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By Dr. A. M. LOW,
A.C.G.I., D.Sc., etc.

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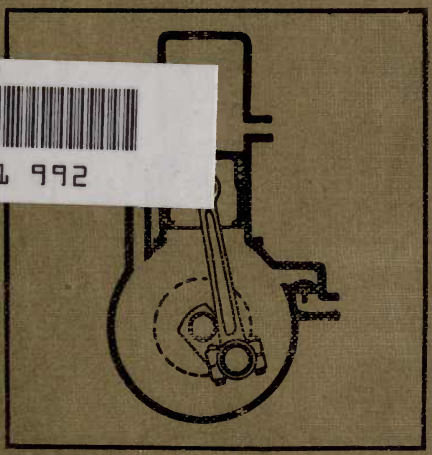

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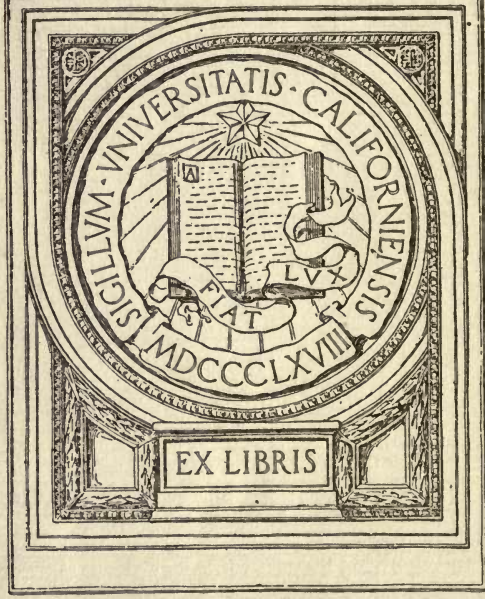

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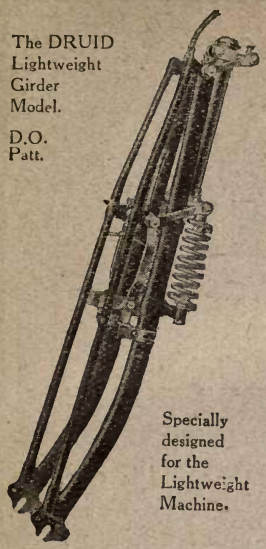

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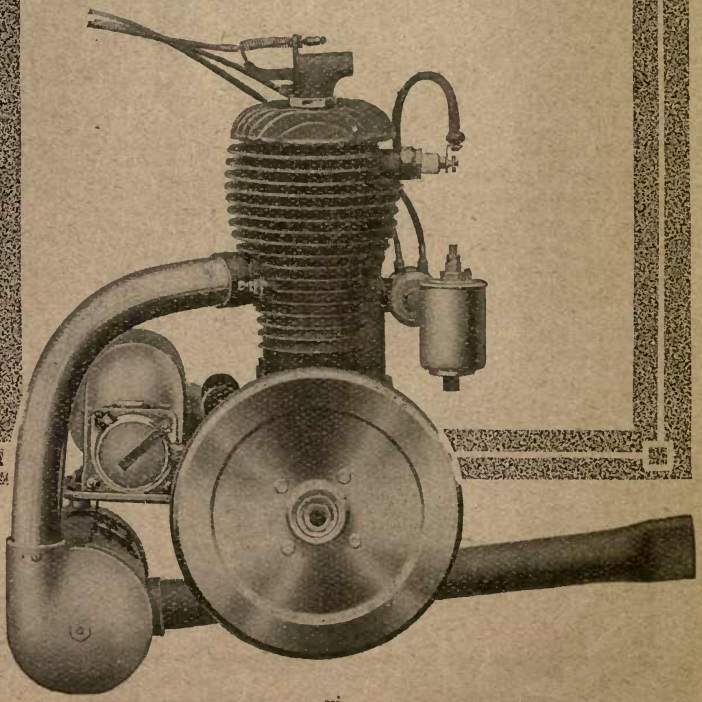

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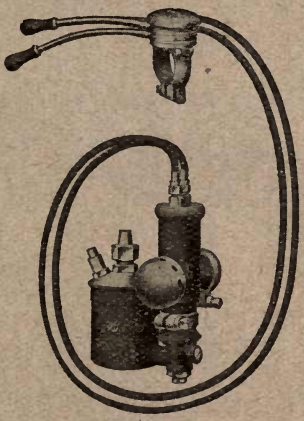

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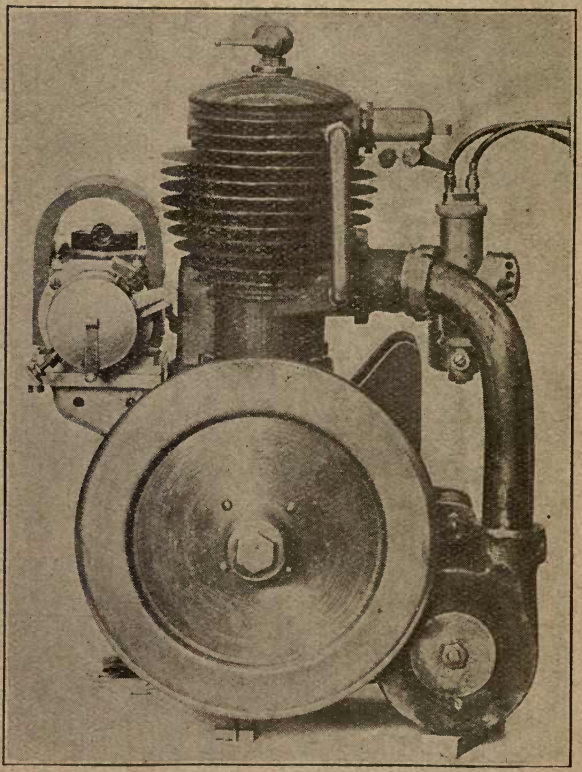

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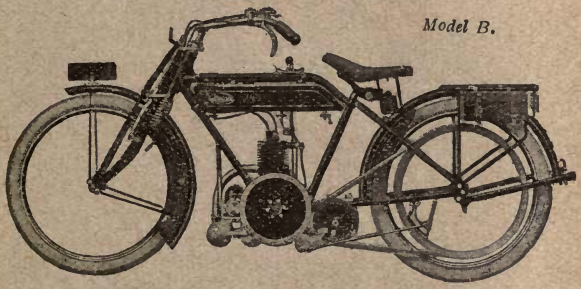

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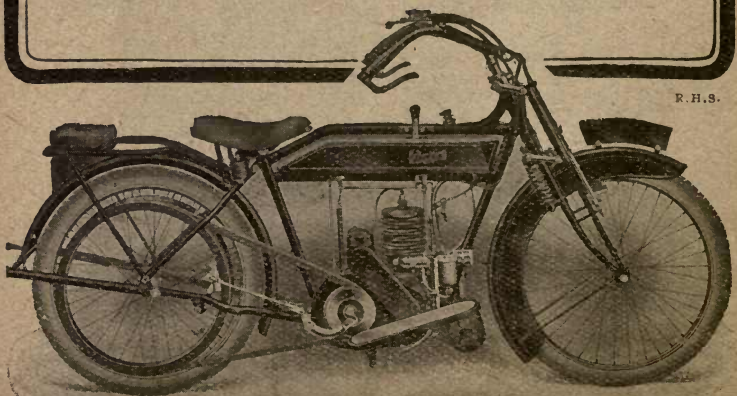

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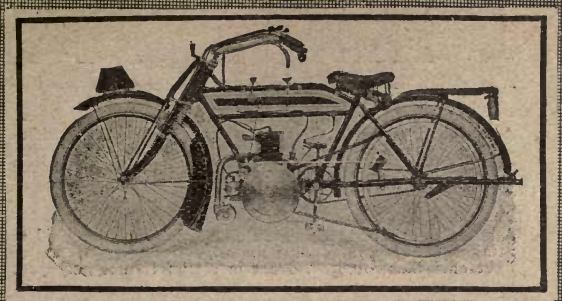

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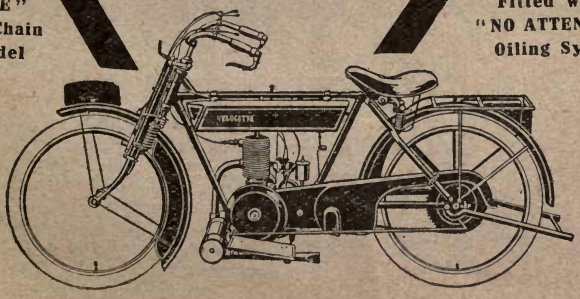

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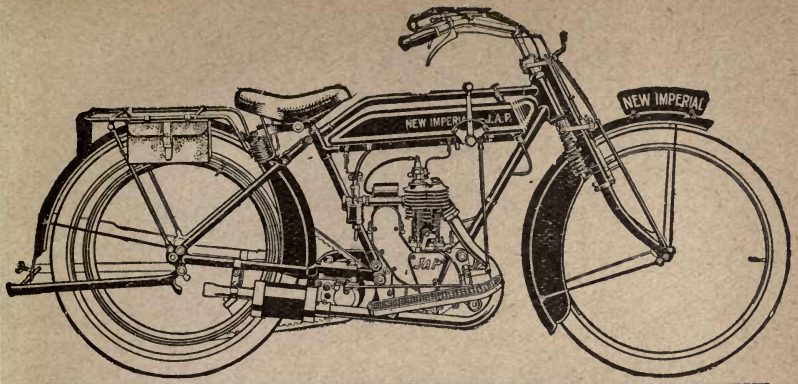

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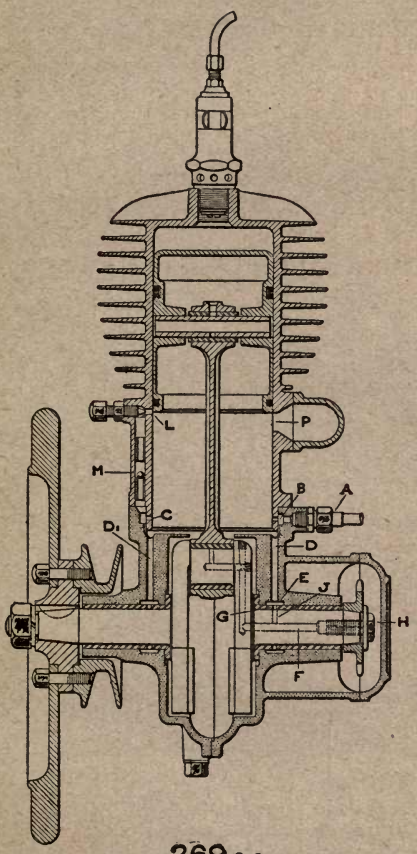

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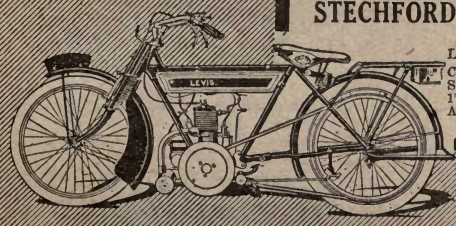

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A FEW DEFINITIONS

For the Assistance of Unskilled Readers

Gas Turbine.—Two- and four-stroke engines are reciprocating engines. In other words, the piston and connecting-rod come to rest at the top and bottom of each stroke. The same applies to the ordinary type of steam-engine, and it was in order to overcome this stopping and starting of the piston that the steam turbine was introduced, in which the power exerted is progressive and continuous. Attempts have been made to introduce a successful petrol turbine in which the explosions would have the same effect as the expansion of steam in a turbine.

Periodicity.—This is a term applied to the vibration of an engine which occurs in certain circumstances. Very nearly every engine has a certain engine speed at which moderately excessive vibration is set up, which does not occur at slightly higher or slightly lower engine speeds. This is known as the periodic vibration of the engine.

Ports.—On a conventional, or four-stroke engine, mechanically operated valves are employed which allow the mixture to enter and leave the cylinder. On a two-stroke machine, however, square or oblong orifices are cut in the cylinder wall to serve the same purpose, the piston allowing the gas to enter and escape by uncovering and covering these ports.

Reciprocating Engine Definition.—The reciprocating engine is one in which the power is applied to a piston which has a definite travel determined

by the distance of the crankpin (to which it is attached by a connecting-rod) from the centre of the mainshaft. It will be realized that the piston and connecting-rod have to come to rest when at the top and the bottom of the piston travel, or in other words, when the crankpin is immediately beneath and immediately above the mainshaft.

Scavenging.—With a two-stroke engine the exhaust, or expended gases, escape through a large port at the bottom of the cylinder. The inlet gas almost simultaneously is forced into the cylinder and is deflected upwards by a baffle plate on the piston. It will be realized, however, that there is still a certain quantity of exhaust gas in the cylinder which the fresh mixture tends to push out as it enters the other side of the cylinder and is deflected upwards by means of the baffle plate. The process of clearing the cylinder of burnt gas is known as scavenging. On some engines special methods are employed in order to clear out the exhaust gases by mechanical means before the inlet gases are allowed to enter.

Stratification.—Stratification of the mixture is due to the different inertias of the petrol and air. As an instance : If the throttle be suddenly opened and sudden suction is applied to the carburetter the air, which is lighter than the petrol, will answer to the suction more readily than the heavy spirit. The suction, however, will eventually affect the petrol and this will then proceed to enter the cylinder together with the air, but in effect we shall have a layer of air and a layer of air and petrol. Supposing, now, that the throttle is suddenly closed, the inertia of the air being less than that of petrol, it will drop off very rapidly, whilst the petrol vapour or stream will still continue to enter the engine and consequently the mixture in the cylinder may be said to be, a layer of air, a layer of petrol and air, and finally

a layer of petrol. It must, of course, be clearly understood that it is impossible for sharp stratification to take place, but the combinations of the charge in the cylinder will not be even.

Thermal Efficiency.—Any given quantity of petrol contains a certain definite quantity of heat, which can be converted into work. If, therefore, an engine is constructed which extracts the maximum practicable amount of power out of that given quantity of petrol it may be stated to be more thermally efficient than an engine which uses up a greater quantity of petrol in order to develop the same power.

Torque.—The torque of an engine may, broadly speaking, be applied to the intensity of the turning movement given to the main shaft, to which the sprocket or pulley is attached which by means of a chain or belt drives the machine. Thus, the torque of a six-cylinder engine, for instance, is more even than that of a single cylinder, owing to the fact that there are six times the number of impulses given to the mainshaft in the same time as compared with the one cylinder.

Turbulence or Whirling.—These expressions are sometimes applied to petrol vapour when acting under certain forces and conditions in the inlet pipe of the carburetter, or in the crank chamber. Owing to various causes, such as the very quick shutting of the inlet valve, the gases are checked when they have attained great velocity, and "pile up" in the inlet pipe, instead of remaining as a steady stream, and become greatly agitated in the inlet pipe. This means that when the inlet valve opens on the next induction stroke the suction has to overcome this hesitation before the petrol gases once more become a steady stream.

Two- and Three-port Two-Strokes.—Considerable confusion exists as to the difference between two- and three-port two-stroke engines.

At the outset the number of ports or holes cut in the cylinder walls to release and admit gases must be dismissed as indicating a difference between the two types. Summed up, the difference is as follows: The engine of every or nearly every single two-stroke power unit is of the three-port type. There is an inlet port uncovered by the rising piston, there is a transfer port by means of which the gas enters the cylinder when the piston reaches almost the end of the firing stroke, and there is an exhaust port also opened at the bottom of the firing stroke by means of which the exhaust gases escape. With a two-port two-stroke the petrol gas is sucked into the crank-case past *an automatic inlet valve* connected to the carburetter, and there is a transfer port and an exhaust port as with the three-port type. To be pedantically correct, therefore, the two-port two-stroke should be referred to as a two-port and valve type.

Water Injection.—If water is injected into the combustion chamber, it will instantly be converted into steam under the influence of the explosion. In some cases this is employed to give increased pressure, but in most cases it is intended to give a more gradual expansion of the exploding charge. The injection of water is sometimes utilized to cool the cylinder walls from the inside.

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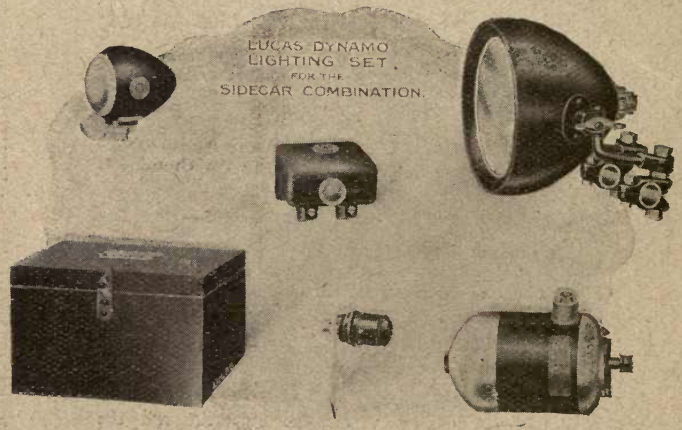

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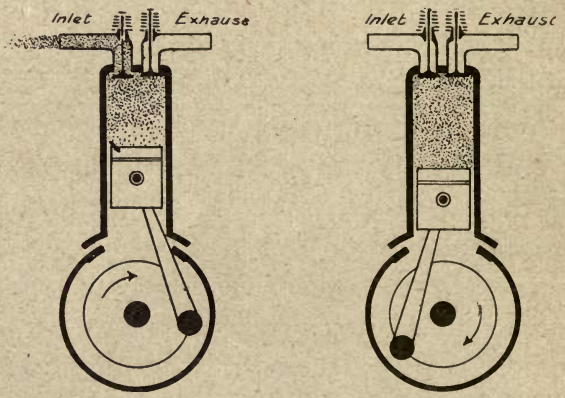
INTRODUCTORY

THE object of this booklet is to write in an absolutely non-technical vein, and this should not be a disadvantage even to those readers who are experts, the idea being to touch briefly upon the most interesting and the most practical points connected with two-stroke engines, so that the reader will be able to form, in his own mind, a clear idea of the operations which are taking place and a reason for the difficulties involved and the various designs adopted to overcome them. In no other way can the driver of a two-stroke engine appreciate and take an interest in the material at his hand, and it is astonishing how well it pays to do this.

HOW AN ENGINE WORKS

The object of all engines, it may be stated, is simply to convert the chemical energy of the fuel into work, and the most obvious way to do this is to burn some fuel like petrol and make use of the power (that is to say, the heat or pressure) generated.

If we could do this directly by causing the pressure to propel the machine along the road, or to act directly on some wheel, we would probably find ourselves dealing with a form of rotary engine; but owing to limitations in materials and other mechanical details we find that in this case so much of the heat generated

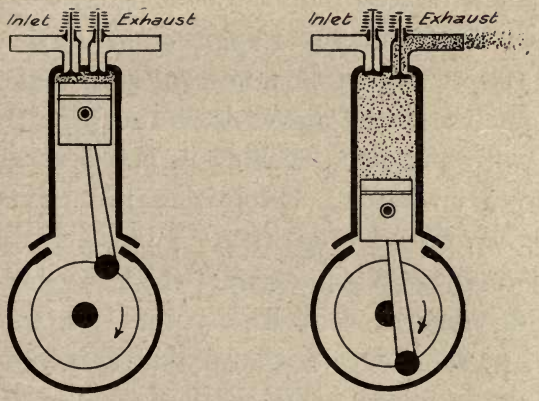


THE CYCLE OF OPERATIONS IN A FOUR-STROKE ENGINE.
Left, inlet stroke; right, compression stroke.

is produced so fast, so to speak, that it cannot be used to do mechanical work through an engine, which if we had one would only give us back a few farthings out of every can of petrol consumed.

On the other hand, if we had several changes

of energy for each time of converting our power, such as by using the petrol to boil water, or compressing our gas separately and then exploding it, we should get not only mechanical complication, but also machine and transference losses.



THE CYCLE OF OPERATIONS IN A FOUR-STROKE ENGINE.
Left, firing stroke ; right, exhaust stroke.

All these points are quite simple, and it is important that they should be borne in mind. It is only natural that the designers of petrol engines should wish to apply the force of the exploded petrol and air (all these points are put in an absolutely elementary manner) as constantly as possible to the work of pro-

pulsion, and that has perhaps been one of the greatest reasons for using what is known as the two-stroke motor, quite apart from any details of construction.

Let us first of all be quite clear as to the meaning of four-stroke and two-stroke engines. Every time the piston moves up or down the cylinder of an engine, it has obviously completed one stroke ; now in the four-stroke engine the piston moves down the cylinder, as shown on page 3, sucking in petrol and air, moves up again, compressing the mixture, the sparking plug then ignites the gas, driving the piston down, which does work in driving the car. The piston then moves up, pushing out the burnt and spent gases. In other words, only one out of every four strokes gives us power, and the type is therefore known as a four-stroke engine.

In the two-stroke engine the actual *cycle* of operations as regards burning the gas is much the same, but there is a *power stroke* during every two strokes of the piston, and it is therefore known as a two-stroke. Page 6 makes the various operations quite clear. Everyone will now expect to read that in a

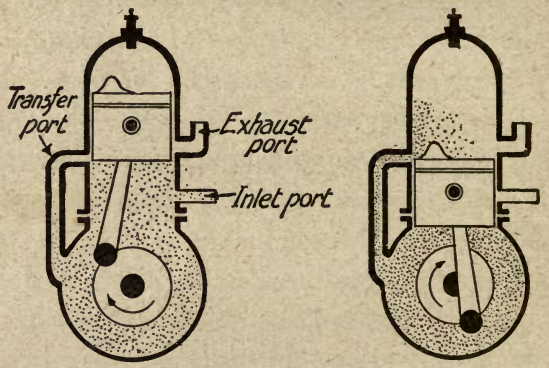
two-stroke engine the cycle of operations is the same, but that the crankcase of the engine is enclosed and used in a certain manner to get the mixture into the top of the cylinder ready for the next explosion; but this is by no means the case, because a two-stroke engine simply means an engine in which there is an explosion every two strokes of the piston, or, in other words, every time the piston reaches one end of the cylinder, and there are obviously many ways of accomplishing this object.

One of the commonest ways is to enclose the crankcase of the engine and make it air-tight, putting the fly-wheel outside and doing away with the crankcase release (which in the ordinary way allows the air compressed by the down-stroke of the piston to be released and stops direct communication with the atmosphere on the top stroke of the piston, thus preventing, or sometimes preventing, a leakage of oil).

In place of this device a connection is made between the crankcase and the carburetter, in such a way that when the piston moves up it uncovers the top of the crankcase or bottom of the cylinder (which comes to the same

thing), and the partial vacuum caused by the piston moving out of the crankcase induces the mixture to rush in from the carburetter.

The piston now commences to descend, the sparking plug having ignited that mixture which is already above the piston, doing



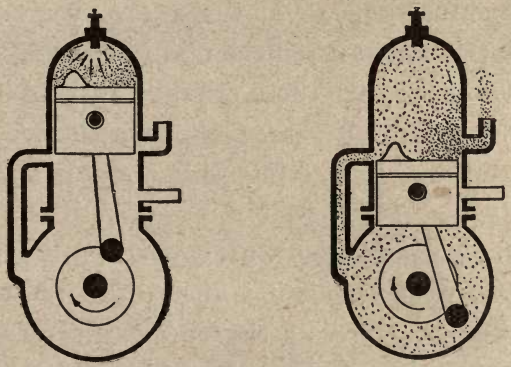
CYCLE OF OPERATIONS IN A TWO-STROKE ENGINE.

Left, crankcase filled with mixture from carburetter at end of inlet stroke. Right, gas compressed in crankcase passing into combustion space.

work on the machine. When it reaches the bottom of the stroke, or very nearly the bottom, the piston uncovers a port in the cylinder wall through which the exhaust gas rushes out. The piston continues its motion, and when it reaches the bottom of the stroke, it uncovers a port connecting the crankcase

to the cylinder—the mixture compressed in the crankcase naturally rushes into the cylinder, driving out most of the exhaust gases and enabling the piston to begin its upward motion, compressing a new charge, ready for explosion, and a new cycle of operations.

It will be seen therefore that in such a single-



CYCLE OF OPERATIONS IN A TWO-STROKE ENGINE.
Left, explosion of charge. Right, last of exhaust gases escaping, with fresh charge entering.

acting machine there is a "kick," so to speak, to the piston every time it reaches the top of the cylinder, and therefore one obtains, considering the weight, a very much better torque (there being twice the number of explosions for each revolution of the crankshaft than in a similar four-stroke engine).

THE LIMITATIONS OF THE TWO-STROKE ENGINE

All this is very pleasant; it means that the engine will be much nicer to drive if all goes well, and it can be driven on a lower gear, because the average horse-power for a reasonable range of revolutions can be better maintained, whilst incidentally there are no valves other than those provided by the piston itself, and only three working parts, the piston, the connecting rod, and the crankshaft.

The great trouble with a two-stroke engine of this kind is that it is inaccurate, and that word best expresses the reason why the old two-stroke engine has not carried all before it. It is an old type of engine, almost if not quite as old as the four-stroke, but it is only recently that it has commenced to cut seriously at the more universal type of engine, and it is only recently that it has begun to come into what should be its rightful own.

Certainly any engine which tends to give a more regular twist on the crankshaft is to be desired. The trouble of inaccuracy, however,

is rather serious, and is possibly due to designers endeavouring to obtain simplicity at one blow, whilst failing to realize that to obtain an explosion at every other stroke is a valuable point, quite apart from the question of simplicity. The modern car or motorcycle is in many ways more complicated than the older pattern, but each unit is capable of doing its work, and capable of doing it better than before, and this should be thought of in conjunction with simplicity, which latter quality provides the final test of value together with true efficiency.

Efficiency means all round efficiency, and an engine which was thermally efficient and used very little petrol might be a six-stroke engine only firing once in every six strokes, but it does not follow that it would be effective for driving a motorcycle or cyclecar, and the necessary transmission arrangements would probably make it very unpleasant, and therefore inefficient *over all.*

THE CRANKCASE AS A PUMP

With the two-stroke engine there are a good many troubles. In the first place, constructed

in the ordinary way that we see on motor-cycles, the crankcase has got to act as a pump. Now we all know how very important is the compression space in a pump, and in a crank-case we cannot get what compression we like because we have got a certain definite amount of space occupied by crankwebs, etc., which we cannot well reduce. We also all know how important is the valve-timing in a pump or engine. But in the ordinary crankcase com-pression two-stroke we cannot obtain proper timing of our valves, that is to say, we cannot give any proper lap or lead to our valves, we cannot make up for the time gas takes to escape through a port in the same way that we can in a four-stroke, where we can set any valve mechanism to do very much what we want. Therefore the crankcase is going to prove an inefficient pump, many times worse than that of the piston in the cylinder of a four-stroke engine, so that when it delivers its charge to the cylinder this charge will not be a full one.

Again, the piston can only allow the mixture to travel from the carburetter to crankcase during an exceedingly short space of time

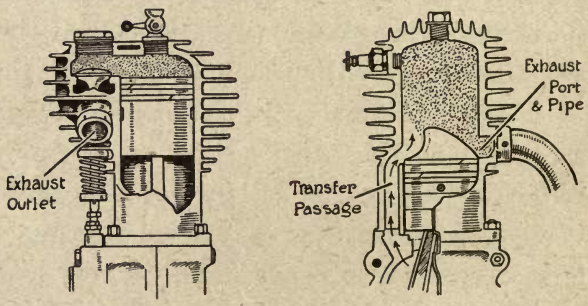
whilst it is at the top of its stroke, and the gas will consequently be partially throttled, still further reducing the actual quantity which rushes on to the top of the piston for each explosion.

There is another point connected with the bad valve-timing of a crankcase compression engine. The exhaust gas is at a considerable pressure, possibly of 40 lbs. per sq. in. at the end of the firing stroke, and therefore if this pressure has got to be made so low that the gas in the crankcase will drive it out we will have to open the exhaust port considerably before we have made full use of the gases, because, as we have already seen, we cannot for mechanical reasons get usually a very high compression in the crankcase. The best we can do is to make a compromise, and therefore not all the exhaust will have left the cylinder, bringing it down to atmospheric pressure when the inlet valve opens, with the result that the inlet gas is impeded, and when it does rush into the cylinder it will mix with the exhaust gases, thus making the mixture, when it comes to be exploded, consist of the mixture proper and a large amount of burnt

gases in addition to those which in a four-stroke engine would not be swept out by the plain motion of the piston.

This is avoided to some extent by putting a plate on the piston to deflect the gases up towards the top of the cylinder, helping them to drive out the exhaust without much mixing.

It must be remembered that these exhaust



RESIDUAL GASES IN (LEFT) A FOUR-STROKE AND (RIGHT) A TWO-STROKE ENGINE.

gases are very hot, which will still further help to reduce the volume of mixture to be exploded and will prevent the change of pressure being so great when the sparking plug fires the charge, reducing the average pressure on the piston during the power stroke.

THE REASON OF HIGH PETROL CONSUMPTION

All this trouble is clearly going to increase our petrol consumption; it is going to make it so that at low speeds with the inlet gas coming in slowly we are going to get mixing; and worse still, it will be helped by bad scavenging—that is to say, an impure firing mixture together with any plugging of the exhaust or other ports which may take place due to burnt oil. This missing is sometimes known as "four-stroking" if it occurs regularly, as it will frequently prevent an engine firing except once in every four strokes, when it gets a reasonably explosive mixture.

Not only have we to consider this, but the reduction of pressure on the piston means that the horse-power will rapidly drop, especially at high speeds, when the exhaust gas has very little time to escape, and a two-stroke engine does not by any means give double the horse-power of a four-stroke running at the same speed. Most of its advantages consist in simplicity and its smooth torque in running; and the actual increase in power is very often only about one and a half times that of a

similar four-stroke, and sometimes less than that, where the port design allows the exhaust gases to carry with them a large proportion of the inlet charge. There is no exhaust stroke proper and consequently no proper scavenging of the burnt gases.

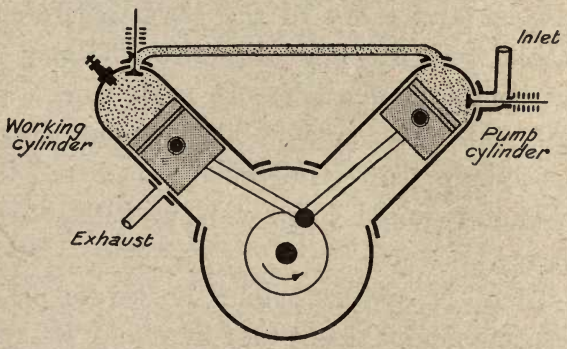
We must not forget that although the two-stroke engine is not properly scavenged, the four-stroke does probably more mechanical work in clearing out the exhaust gas than is lost by actual friction between the two charges in the two-stroke. A very important point is clearly that of keeping the crankcase air-tight, by means, for example, of washers held up to their work by springs; this can be accomplished with fair success, especially if properly lubricated.

DIFFERENT TYPES OF ENGINES

The avoidance of these troubles has been the cause of an enormous amount of work and worry on the part of designers since the very earliest stages of the internal combustion engine, and there have been a number of two-stroke engines on the market, dating twenty and thirty years back, whose principles

have worked, and worked quite well, on motor-cars and boats. Most of them have simply had one object in view, and this has been to avoid the use of the crankcase as a pump.

This at a blow avoids the danger of crank-case leakages to the air, and enables us to make the pump efficient and make it deliver any amount of gas we want, so that we can, if necessary, even increase the compression pressure and thoroughly scavenge our engine.



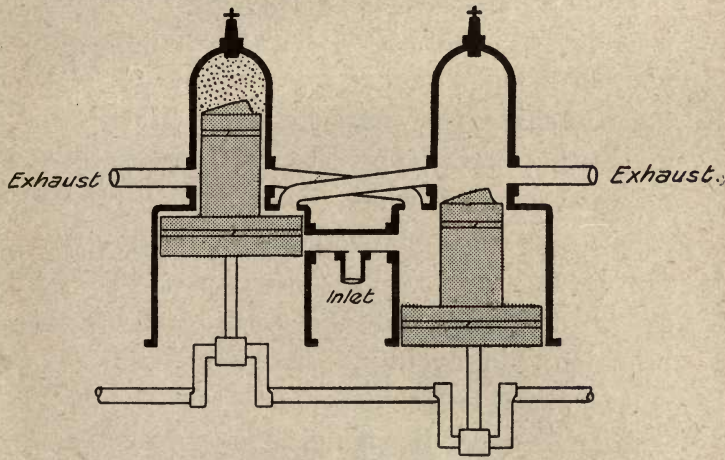
The type of engine having a separate pump chamber gains in thermal efficiency, loses in mechanical simplicity, and only equals the four-stroke in explosions per cylinder.

Unfortunately, this does away largely with simplicity, and it also adds a cylinder to our engine which is doing negative work, increasing space, largely increasing friction and mechanical complication, and altogether making the

engine rather unattractive from the point of view of compactness and power. It enables us, on the other hand, to vary the compression pressure, and this is a great point, for we can get good scavenging; we can get a high effective pressure even though we have to pay for it with the work done in driving the pump cylinder. Another point is, that if we have a separate pump we can more easily use valves which would enable us to time the exhaust and entry of the gases accurately, thereby raising the volumetric efficiency of the engine as a whole. In other words, we can make the amount of gas put in by the pump correctly proportioned to the amount required to provide us with a new charge.

There is another point in favour of a separate pump; this is that by its use we can, if necessary, scavenge our engine directly with air, and not only pump in a mixture of air and petrol in various quantities, but also if we wish send a blast of air through the cylinder to clear out the burnt gases before the next firing stroke, thereby keeping the whole engine cool.

There have been a large number of engines of this type on the market, amongst others being the Duplex, in which there are two pistons, as shown below.



DUPLEX PUMP CYLINDER ENGINE.

In the pump engine with the stepped trunk pistons each working cylinder is served by the opposite pumping cylinder.

Now, with a two-piston engine, if we want to provide a pump cylinder, one of the simplest ways is to place the pump piston between the other two working cylinders—a plan which has been frequently adopted on large two-stroke Diesel engines. Another method of obtaining a pump is to use what is known as

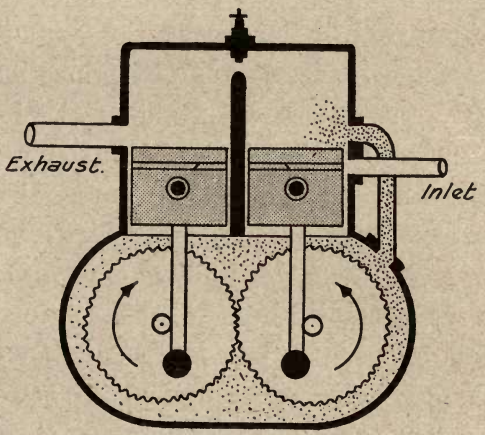
a stepped or compound piston, such as has been adopted on steam engines ; and this has been done in the case of some of the Duplex and many others.

In this case the bottom portion of the piston is made large, and this moving up and down in another cylinder acts as a pump and can be made to charge the working cylinder either by uncovering ports or by means of a properly operated valve, in which case a high thermal efficiency is obtained together with the beautifully smooth torque of most two-strokes, whilst careful designing, and, above all, careful lubrication, can avoid all undue mechanical and frictional losses.

Another type of engine is known as the Lucas, in which two pistons move up and down together in their respective cylinders placed side by side, and this results in a fairly good pumping action from the top side of the pistons and smooth running, as the combustion chamber is common to both cylinders. The combination of working piston and pump-piston into one unit is quite likely to receive more attention, but need not concern us at the moment.

THE VALUE OF SIMPLICITY

It is very interesting to take note of the points from different types of engines and to see in what way their designers have endeavoured to cover some of the objections we have mentioned, such as the mixture of the



The Lucas Engine has a common combustion chamber. The gas must therefore be partially vaporized to avoid cylinder condensation in the long inlet passages.

exhaust and inlet charge, the inefficiency of the crankcase as a pump, and faulty timing of the various motions. Practically speaking, there are very few engines on the market other than those with crankcase compression, and this is possibly a proof of the value of

simplicity, although we must bear in mind that it is largely controlled by questions of price, for there is no reason why a two-stroke engine should be looked upon as one having only crankcase compression. In fact there can be no doubt that this misunderstanding is responsible for many hard things that have been said from time to time about the two-stroke.

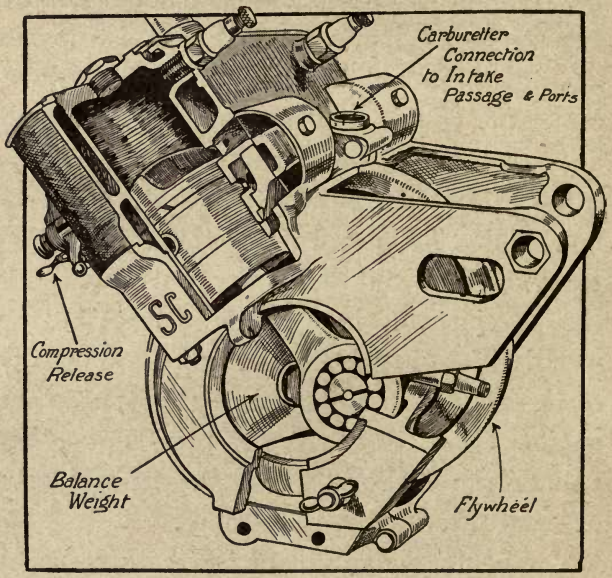
There are many dozens of engines on the market, but from a scientific point of view they differ very slightly in their mechanical details, and it is therefore interesting to notice how their working is affected by their construction. The great object of all designers has very naturally been the production of a smooth impulse engine, and one, moreover, which is capable of producing its power at low speeds, thereby avoiding many of the losses which are due to the shock and general irregular running of the four-stroke, or much more irregular impulse engine, at low speeds. The ordinary standard four-stroke engine when running slowly wastes a terrible amount of power through shock, and becomes a most unmechanical proposition at a speed of revolution far higher than that at which the

two-stroke is capable of averaging with reasonable economy, and with possibilities of petrol consumption which can be more varied to suit running conditions.

It would seem remarkable that advantage has not been taken of the multi-cylinder two-stroke engine, and no doubt cheapness has again entered the case, though we must remember that one of the very best designed and best running machines on the market is fitted with this type of power unit. Possibly no machine is so novel and at the same time so really well thought out as the Scott. It is not the province of these notes to describe the peculiarities of each engine, which are usually to be summed up in two ways: first, keep the engine clean, and secondly, do not allow volumetric efficiency to fail by the springing of leaks anywhere in the system.

The Scott engine illustrated in these pages is a two-cylinder side-by-side, and forms a most valuable study in its design. It is capable of producing power regularly at low speeds; it has enabled the winner two years in succession of the Tourist Trophy to run his engine at a speed averaging about 1000, not

much more than half some of the others; this result has only been obtained after experiments which have taken somewhat the form of our preliminary discussion. The Scott engine has been cooled in various ways;



THE SCOTT TWO-STROKE ENGINE.

it has been provided with water-cooled heads, which were found insufficient, and it has been provided with distributing valves, driven, of course, from the engine shaft, but the added power was not apparent after wear

of the parts had taken place. This shows us, by the way, how simplicity enables a machine to keep its tune, and provides an object lesson of the fact that a two-stroke engine has usually a positively operated valve gear. This is a very great advantage, for with any poppet valve the actions of opening and closing are largely controlled by the weight of the valve and the strength of the spring, so that no number of cams can enable us to tell with certainty what our valve is doing after a few hundred miles running.

If the valves of a two-stroke are kept clean this trouble is not apparent, and a multitude of sins are consequently avoided. The Scott side-by-side twin is an ordinary crankcase compression engine, but it is capable of being reasonably well balanced, and by means of pressure-retaining washers the two crankcases are separated and maintained reasonably air-tight whilst the gases pass through the transfer ports, which can also be easily kept tight with little trouble.

The operation of the engine is extremely simple, the gas being simply compressed in the crankcase and driven into the working

cylinder by means of the ordinary three ports and passages, no special lubrication being necessary. Nothing can be more simple, and makers have not found it worth their while to incorporate complications.

It is not easy to pick any one two-stroke machine and say that it is better than another, for with the exception of their lubricating devices, there is very little difference as regards operation, except in the arrangement of ports. Different designers have adopted various designs to get smooth entry of the gases without throttling, and different arrangements of passages for the gas.

METHODS OF LUBRICATION

Two-stroke lubrication has been a source of difficulty in times gone by, because a two-stroke usually runs hotter than a four-stroke unless the cooling is more carefully arranged, and, indeed, if its efficiency was up to the four-stroke for each cubic centimetre it would be bound to become hotter, there being less time for radiation. Lubrication systems are different on almost every machine, and it is

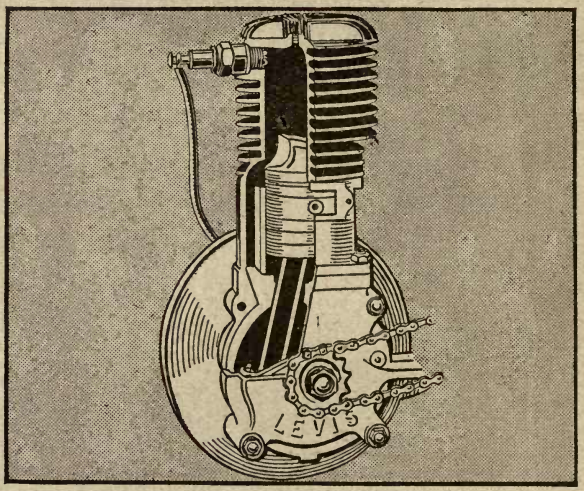
perhaps a mistake to jump to the conclusion that they need vary from those employed on good four-stroke motors.

Undoubtedly, the best system for most parts is that of a direct force pump feed, but we must not forget that as we are sucking in petrol and air into crankcase the latter is acting as a vaporizer and dissolving some of the lubricant. This being the case, it is possible to supply without any mechanical arrangements most parts of the engine with an excellent lubricant in the form of oil dust in the mixture. All one has to do is to mix oil with petrol, and when the latter evaporates, the oil will separate out in a very fine form and then be carried regularly and in some proportion to the load to every working part.

Some of it will, of course, be burnt with the mixture, but, nevertheless, it provides a very simple means of lubrication when carefully graduated, and owing to the fine form of the oil it will frequently avoid carbonizing without having any effect on starting in the ordinary machine.

Some mechanical control would be an improvement in other than very small engines.

An excellent example of lubrication is provided by the Levis machine, which is one of the most remarkable machines made for its size. Two-stroke engines have certainly distinguished



THE LEVIS TWO-STROKE ENGINE.

themselves in the Tourist Trophy Race, which rapidly finds out bad design, and by covering the mountain course with a single gear these simple two-strokes have put up a performance which can only be described as remarkable. In the Levis engine the mechanical arrange-

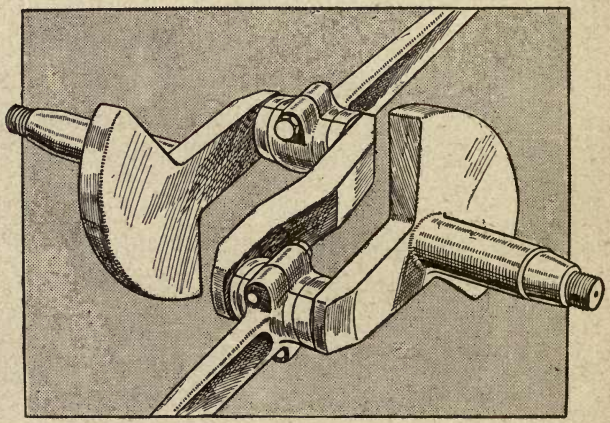
ments are quite standard; the engine has the usual three ports and the cycle of operations is identical with all other machines.

DIFFERENT TYPES

Its ports, however, are of more than passing interest as, whether intentionally or otherwise, they have been arranged to communicate with their passages very freely—a good point making for smooth running and economy. The lubrication system is distinctly good in both design and manufacture, and it is more accurate possibly than the oil fog system, though the latter may be of advantage as regards the piston. With the Levis engine all troubles of mixing the oil with the petrol are done away with, because the oil is led to a drilled crankcase, no oil being directly admitted to the crank to become churned up. It is fed through the magneto drive side of the main bearing and is thrown by revolution of the crankshaft through the ducts to the big end, whilst the bearings are lubricated by holes from the hollow crankshaft which communicate with the journals. The gudgeon pin

is also hollow, and is fed with oil passing up the connecting rod on to the pin and thence on to the walls of the piston, which is directly lubricated.

Practically no trouble seems to be experienced on any engines of this make as far as oiling is concerned, providing all these ducts



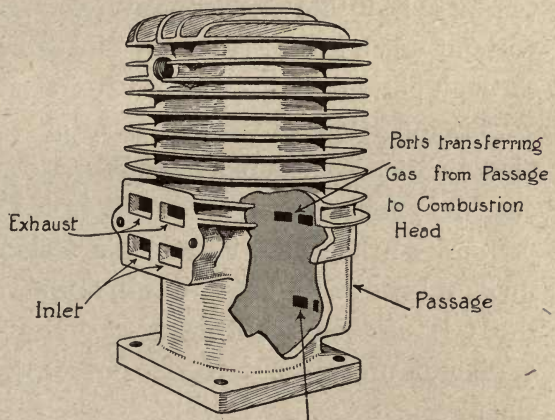
TYPES OF TWO-STROKE ENGINES.

Balanced two-throw crankshaft of the Levis horizontally opposed twin engine with connecting rods in position.

be kept clean. This two-stroke engine, beyond being kept clean, requires practically no addition, and this is a good point on any well-designed unit of a similar type.

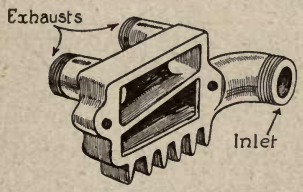
An engine in which port design has received

marked attention is the Connaught, which is one of the very first small two-stroke air-cooled engines to be introduced. Its action needs no particular description, but the



CONNAUGHT CYLINDER SHOWING HIGH EFFICIENCY INLET.

The gases are sucked in through the inlet ports, through ports cut in the piston, are compressed and are admitted into the cylinder on the opposite side of the entry by means of ports cut in the cylinder walls registering with the entrance ports.



Exhaust and inlet manifold—a great feature of this engine.

induction port is placed immediately beneath the exhaust, thus having a tendency to cool this side of the engine, and at the same time preventing condensation of the mixture,

which in the case of heavier fuels is a distinct advantage. The ports also of this engine are narrower than the usual unit, but extend much further round the cylinder, which enables the timing to be rather more effectively carried out without much loss of efficiency due to friction through ports and passages of varying sizes.

This question of timing has, of course, already been considered. If properly carried out, it enables one to maintain effective pressure on the piston for a longer period with quick release and a longer dwell, during which the mixture can pass from carburetter to crankcase preparatory to the down-stroke of the piston.

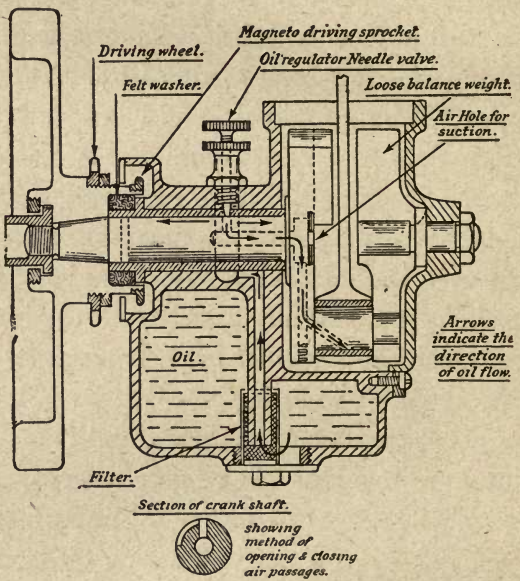
A piston of this engine not only acts directly as a valve, but it is actually used to communicate with the transfer port connecting the crankcase to the working cylinder by being unduly carried over into the combustion space ; it needs careful design of the piston to avoid gas friction losses, the same point being obtainable by a plate across the small end. The Connaught engine, however, has been successful on this score ; its cylinder is offset to obtain a more direct thrust whilst

the crankshaft is maintaining a running fit in the crankcase by the use of compression rings.

Lubrication is by mixing the oil with the petrol, so that as complete vaporization begins to take place in the crankcase the oil is left in a fine form to lubricate every bearing. A great point has been made of free exhaust, two ports being provided; and it may be that this is valuable, because should a two-stroke engine be at all choked as to its ports, scavenging is largely destroyed, and the exhaust mixes with the inlet charge on account of the latter being unable fully to drive out the burnt gases which are impeded in their passages by burnt carbon or webs in the castings. This is a frequent cause of "four stroking."

Another machine having a very neat mechanically arranged rotary oil pump is the Veloce. This has a pump drawing oil from a sump in the crankcase, and is fitted with an oil indicator, so that so long as the pump is working the rider cannot doubt that all must be well. Another system now adopted in the Veloce is that of lubrication by means of the vacuum in the crankcase. In the mainshaft a passage is drilled which acts as a valve,

opening and closing at a specified time, the amount of oil being regulated by a small valve. The flow of oil reaches the crankshaft bearings and big end. The piston has a ledge formed



THE LUBRICATION SYSTEM OF THE VELOCE.

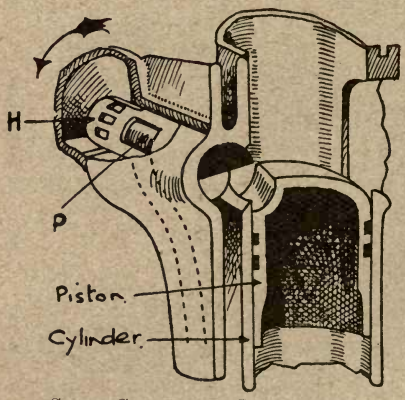
inside, which catches the oil thrown from the big end, and holes are drilled which take the oil to the cylinder walls. The little end has a deep groove which catches the oil thrown from the big end bearing.

Nearly all these units could contain suitable gearing in one with the crankcase; but this is standard practice in some cases and does not therefore require any further information than that provided by the maker's detailed drawings and instructions. The Peco, Triumph, and Clyno units are all excellent examples of their kind; they differ only in details of construction as regards their operation.

Before going on to describe the nature of engines with different types of ports, attention should be paid to the Scott rotary distributor valve, at one time fitted to these engines for racing. The Scott machine affords an excellent example of standardized practice, and this, together with such engines as the Levis, should be borne in mind by the reader who wishes to gather information from these notes. The Scott machine used to be fitted with a separate feed to each crankcase, which had, of course, to be relatively air-tight.

The oiling system now fitted is very simple, all lubricant being fed to each crankcase

through a small hole on the inner face of the roller bearings to the main shaft somewhat after the style of the Veloce ; these oil ways are exposed at each revolution to the full crank-case suction, which ensures a reasonable degree of automaticity to the feed, although it is not under actual pressure, beyond that supplied by the motion of the crank-shaft and reciprocating parts. The oil is fed to these bearings through a sight feed, which is made in the form of a plunger pump and spring with a screw operated needle valve as a regulator.

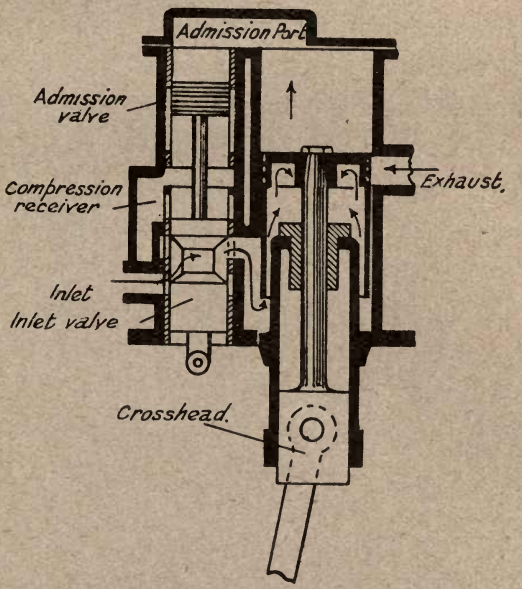


SCOTT CRANKCASE COMPRESSION ROTARY DISTRIBUTION VALVE.

P. Valve.
H. Port housing.

There is at present no engine on the market with a pump feed as well as an oil spray other than those operated by mixing petrol with the

oil and except in the case of the M.I.P., where the oil, being fed to rotary distribution valves, is not only pumped to bearings, but only blown on to the working pistons.



TYPES OF TWO-STROKE ENGINES: THE VALVE GEAR FITTED TO THE HEWITT-COOPER ENGINE.

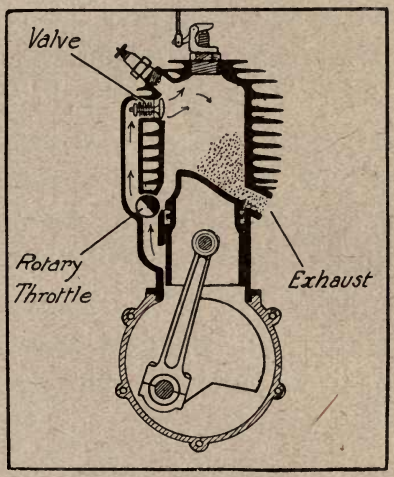
There are six cylinders, each fitted with pump piston as an enlargement of the working piston, and these are cross connected to charge in the ordinary manner through direct operated piston valves. The mixture is drawn from the carburetter by the pumping piston situated below the power piston, and is forced into the *next* power cylinder through the piston valves, which are driven by eccentrics on a sub shaft. These valves enable proper timing to be obtained independently of the piston's direct motion.

THREE-PORT TYPE

All these engines are, as will have been noticed, constructed with three ports: one to the carburetter, one transfer port to take the mixture from crankcase to working cylinder, and one exhaust port, so that they are known as the three-port type.

This expression, strangely enough, is not used to any extent in America, which might almost be said to be the home of the two-stroke engine. A large number of engines are constructed in the States for marine work, but they have frequently only two ports, the third port being exchanged for one ordinary automatic valve, as shown on p. 37, which leads to the carburetter, so that the mixture is sucked from the carburetter into the crankcase, and then, when the piston commences to descend, the automatic valve closes, preventing blow back. The remaining cycle of operations is identical, and the gas passes through the transfer port into the cylinder proper.

These engines, of course, are quite simple, and usually introduce an automatic port valve which is little better as regards accuracy than that operated in the piston wall by the piston itself; all these valves controlled by springs are not force closed and therefore cannot be relied upon, especially for any length of time.



In the Wilks Engine a separate throttle closes the transfer port at low speeds, and clean gas sweeps on to the plug direct. The higher the speed the less mixture enters by the separate passage.

This defect can be avoided to some extent by the use of mechanically operated valves, but in this case we commence to do away with the great advantage of simplicity, which is to be had in most two-stroke engines in cases of

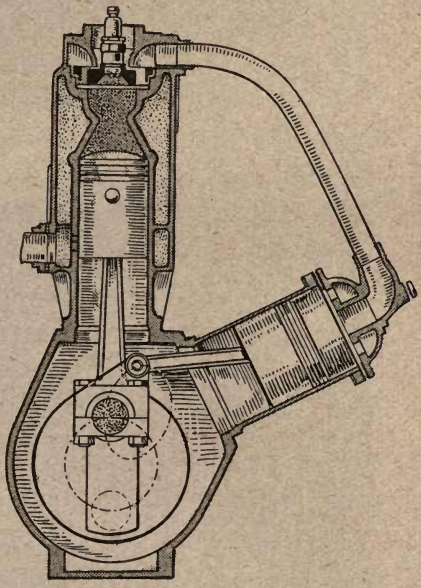
two-port engines, especially if of the type where a separate pump is used, instead of the crankcase, to supply the mixture. It is possible to scavenge by the crankcase and to ensure that when the enriched mixture passes in from the carburetter it will meet air only and not exhaust gas.

In order to avoid the use of petrol "gas," which often becomes reasonably vaporized in the crankcase, it has been actually suggested (and tried with some success) that air only should be compressed in the crankcase, and a valve or port permit this air to be driven into the working cylinder followed by a blast of very rich mixture through a carburetter jet or valve, whose lag will allow air to pass first with a gradual increasing richness of mixture until the proper explosion quantities are reached. It is claimed that this enables fresh gas to meet the plug for slow running, together with the avoidance of petrol in the crankcase and good scavenging.

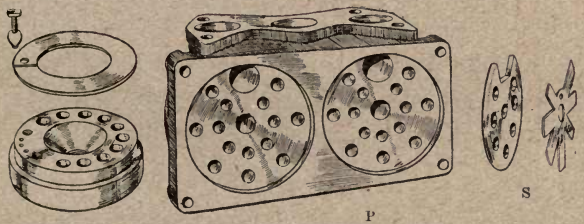
Another engine in which this has been carried out is one with a separate pump altogether, such as is provided with a 90° twin, one cylinder operating as a pump. In this

case, the mixture can be enriched or the pump made as efficient as required, although one loses somewhat in mechanical efficiency, simplicity, space, and neatness.

It enables one, however, as has been done in the Ricardo engine, to obtain excellent balance, even loading of connecting rods and the avoidance of periodicity.



General Sectional Elevation of Ricardo Engine.



Ricardo Pump Cylinder, Single Two-stroke.

The pumping cylinder heads (P) are detachable, and the working cylinder seat and valve are flat (W). The pump cylinder valve is also of flat bronze plate (S), and is supported by a star-shaped piece of pressed steel shown beside the valve itself.

THE POSSIBILITIES OF THE TWO-STROKE ENGINE

It is never possible to write in a complete manner about the future of any subject without going deeply into all the principles underlying it. In these chapters such treatment is not possible, their object is to bring forth to the reader in as simple a manner as possible some of the principles and troubles which beset the engineer whose ideas would like to run riot on two-stroke design.

The points which it has been endeavoured to bring out are mostly incorporated in the description of two-stroke machines and operations with which we have already dealt. It would appear, and with some justice, to everybody, that if we are using explosions in a motor to drive that machine—and if these explosions do not take place continuously—it would certainly be desirable for them to occur as frequently as possible. This the two-stroke engine enables us to do. It gives us an explosion every time the piston reaches the top of its stroke, and it enables us frequently to use a very simple engine, and one which

does not necessitate the use of any springs, owing to its simple crankcase compression.

If then we have an engine which gives a better torque and which is far more simple, how is it that it has not swept the board? Prejudice based on inefficiency covers much of the ground as a reply to this question. We are dealing with a gas, or we would like to be dealing with a gas. Now with the liquid petrol or with the liquid known as Benzole, or any of these fuels, a considerable amount of heat is required to turn the liquid into a real gas, because of its latent heat of vaporization.

THE CARBURETTER

The ordinary engine and most two-stroke engines make use of a device which has been miscalled a carburetter, and this carburetter professes amongst other things to turn the liquid into gas, so that it may be used in the engine. It has been very conclusively proved that this is not the case, and the fact that in a two-stroke engine it is possible to mix oil with the petrol without the oil condensing out in the inlet pipe proves that the petrol exists in the form of small particles, part of which vapor-

izes gradually as it passes up the inlet pipe and into the cylinder, and part of which is burnt in the form of small quantities of liquid petrol in the engine. This naturally results in a considerable wastage of fuel, much of its available heat not being produced by combustion. But it does more—for it not only occupies space which might be taken up by efficient mixture (that is to say, mixture which gives a high maximum pressure on explosion), but when the engine is running slowly, it is obvious that an efficient mixture is not one which explodes very rapidly, because the piston in this case would be unable to move quick enough to take up the heat of explosion by expanding the charge, the result being that too much of the heat is given to the cylinder walls. Pre-ignition or knocking would probably result from the over rapid rise of pressure of the charge setting up strains in the working parts of various kinds, at the same time destroying the oil film. On some heavy oil engines the fuel is deliberately allowed to vaporize in the cylinder.

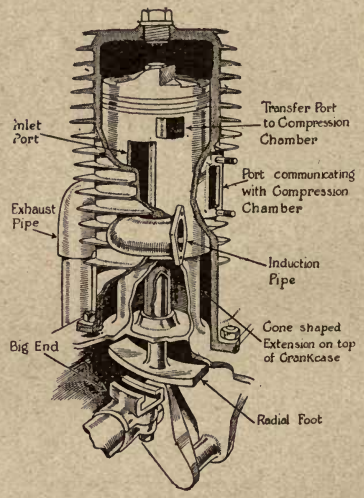
COMPARISON WITH THE FOUR-STROKE

The two-stroke engine is far too often assumed to consist of the stock motorcycle type engine with crankcase compression, and whilst it seems possible that the simplicity of this type will end in most of its points being adopted in preference to more complicated designs, it would appear that its relative inefficiency has been responsible for the fact that many people refuse even to this day to consider it as a serious rival to the far more highly thermal efficient four-stroke.

This is really nothing less than a great mistake, because it is possible undoubtedly to obtain a two-cycle engine of efficiency comparable to the four-stroke. Which will be readily admitted, when we remember what an enormous amount of work has been put into the four-stroke machine, whilst only too many small two-stroke engines have been carelessly built and, worse still, built by people who have been tempted to enter on their construction by their "beautiful simplicity." Whilst these engines are usually simple to construct the underlying principles which should guide their designers in all details such as port design and

port area are really very complicated and need great study, knowledge, and experimenting on the subject.

Let us first of all always bear in mind that it is better to give an impulse to our piston as often as possible, and it is to be hoped that this fact will assist us in approaching the problem of the gas turbine.



TYPES OF TWO-STROKE ENGINES.

Premier Twin two-stroke, sketch of one cylinder showing piston, coned extension of crankcase and foot and guide. The radial foot slides in the big end.

THE QUESTION OF OVERHEATING

There was a time when the two-stroke engine was condemned on account of overheating. It used to be stated that a large two-stroke engine would never run cool because so much

more heat was being put into the cylinder walls, especially on account of its somewhat high petrol consumption and lack of thermal efficiency. This is more or less a fallacy, for it is easy to build large two-stroke engines if proper cooling is arranged, and cooling can be obtained not only by water being applied externally, but also by water injection on the hot surfaces internally and by an air-blast internally, such as is now common in the large Diesel high compression two-stroke.

When it is remembered that a few years ago, when only very low compression engines were common, it used to be an ordinary sight to see motor-cyclists waiting at the foot of every little hill, and often fanning their engines to cool them, it will be admitted that if it is now so simple to keep our small ultra-efficiency engines cool the same improvement in design should allow for easy cooling of the corresponding two-stroke, not to mention the saving to be effected and the many advantages of water cooling.

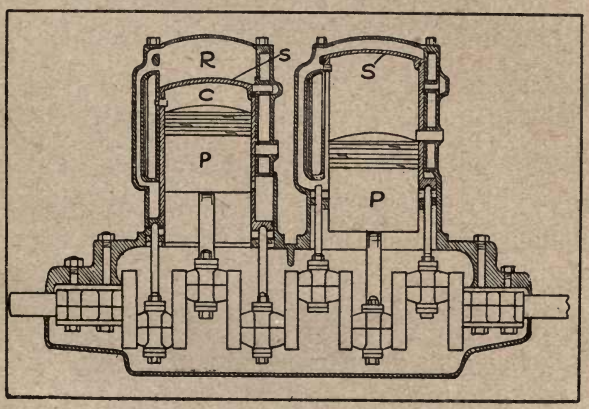
THE PETROL TURBINE

Most of these arguments would seemingly apply to the petrol or petrol steam turbine. When we remember how important it is for the correct proportion of heat in any engine to be retained, we can easily realize that the fact of a two-stroke engine warming its mixture in a pump or crankcase might be greatly advantageous in leading to proper vaporization of the fuel, with consequent economy, the possibility of control of combustion, and the use of various kinds of fuel.

The Petrol Turbine may be classed somewhat under the same heading, because however much heat we may have over the amount which we can use up in doing mechanical work on the blades, we must remember that this heat could be used to warm the mixture, prepare the fuel, or to vaporize water which might be expansively burnt through a petrol jet or in actual contact with the fuel whether liquid or solid. Not only this, but the control of temperature which is practicable in a two-stroke engine leads one to believe that it might

be possible in a turbine engine to cause an intentional lack of turbulence with rapid combustion or scavenging, in such a manner that the resulting state of stratification would prevent the hottest part of the first flame burning or even reaching the mechanical parts with all their liability to break down.

This subject very naturally leads to discussion of provision for producing a mixture under pressure and incidentally of providing for its proper atomization and consequent vaporization, which can be carried out directly. The



TYPES OF TWO-STROKE ENGINES.

Two-stroke engines having double piston sets can be made to give good scavenging and charging. C is the clearance space for the working pistons P and R of the duplex pumping pistons S, which deliver into the next working cylinder.

two-stroke engine has largely suffered through its thermal inefficiency. Now a thermally inefficient engine, if it produced power at a reasonable rate of speed which could be easily converted to useful work on the road wheels, might provide an overall plant of high efficiency, and this thermal inefficiency has been largely due to the trouble experienced with crankcase engines.

Crankcase engines are very inefficient from a volumetric point of view, and they naturally use rather a lot of petrol, which is by no means the most important point to be considered.

If two-stroke engines have been adopted with success in cases where constant speed and fuel consumption is of the greatest importance, surely when fuel consumption is purely a secondary consideration, the bogey of thermal inefficiency should not be raised.

GENERAL DETAILS

Let us consider the matter briefly and from a broad point of view. The majority of two-stroke engines give more power than a four-stroke of equal capacity, and, generally speaking, they will not run up to high speeds

whilst maintaining their power curve to any reasonable extent. This is due chiefly to two causes. We have in most of these engines the crankcase acting as a pump, and as it is of relatively large dimensions its volumetric efficiency is very low. Not only this; but even if its efficiency as an actual pump were to be 100 per cent it would be impossible, on account of the port sizes and transfer pipes and valves, to get the whole of the gas from the crankcase into the cylinder. At high speeds especially this means a rapid reduction in the mean effective pressure.

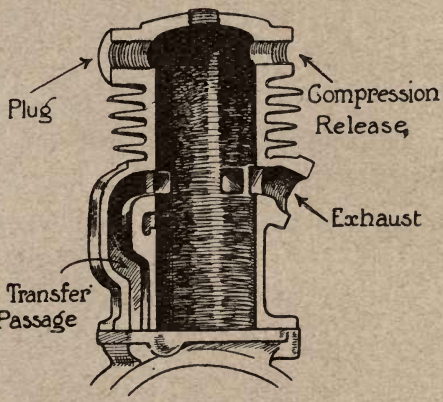
In addition to this, the gas before explosion is not by any means pure, because scavenging is bad and there is no actual exhaust stroke, so that when the piston travels down, the exhaust (however early it may take place) has got to be driven out by the incoming gases. It is not pushed out and it has little time to escape. These incoming gases mixing with the charge, as has already been explained, greatly reduce the pressure on the piston during the firing stroke. And as the piston is acting as a valve it is clear that if it were not

for the fact that it is moving very slowly, relative to crank angle turned through at the ends of the stroke, it would be impossible even by off-setting to allow sufficient time for the charge to pass into the cylinder. The charge has got to be passed in very fast, which means big ports, and however carefully the engine is designed so as to keep the ports tight on the inlet side, it is difficult to prevent some leakage.

In addition to this, the exhaust gas raises the temperature of the incoming charge still further, reducing its effective volume and the possibility of giving a high mean effective pressure. If the gas is allowed to enter the working cylinder slowly its amount will be restricted and a worse trouble will make itself felt, because it will not be deflected up past the deflector on the piston quick enough to give any turbulence and quick enough to reach the sparking plug with fresh mixture, enabling the engine to run without missing or four-stroking at low speeds.

IMPORTANCE OF PORT DESIGN

This only shows how important a matter is plug position and how important it is to design all pockets, valve areas, and transfer volumes (not to mention the crankcase and piston) with the greatest care, collecting, as far as possible, what temperatures are likely to be met with, and experimenting to find the



TYPES OF TWO-STROKE ENGINES.
Section of a Dayton cylinder—opposite and duplicate ported.

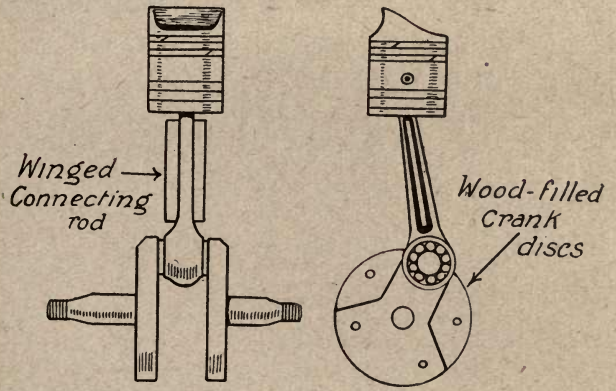
position and state of the gas and whether the vapour is wet or dry. This is all too often done by rule of thumb methods by people who do not appreciate that one millimetre allowed on the piston and a few cubic centimetres

difference in port passage volume may utterly ruin the engine. Petrol, like all liquids, has a certain latent heat which must be put into it to procure a dry vapour and not a mixture of small petrol particles and gas. A two-stroke engine offers great possibilities for the proper production of vapour, but it is possible to condense the gas in the ports and in the crank-case.

In the laboratory this can be done with practical certainty, so that when engines are being used during the varying conditions of speed and temperature of ordinary surface cooling much bad running can be accounted for and put down to lack of care in design and experimental research. Irregular temperature rise is seldom allowed for to this day, and deflectors are too often treated as gas ducts.

THE DESIGN OF SHORT STROKES

A two-stroke engine is very hard to construct to long-stroke designs if crankcase compression is to be used, because although it enables valve position to be more reasonably timed



By the use of winged connecting-rods and of wood-filled crank discs, a blowing action is obtainable to raise the crankcase or pump compression. *Right.* Rivets to hold wood cheeks in position on balanced webs.

and a certain amount of accuracy to be obtained (which would otherwise necessitate very complicated machining methods), it means a crankcase of large volume, which is almost fatal. It is surprising that more trouble is not taken to reduce crankcase volume by such a simple method as using the crank cheeks filled up with wood and covered with lead.

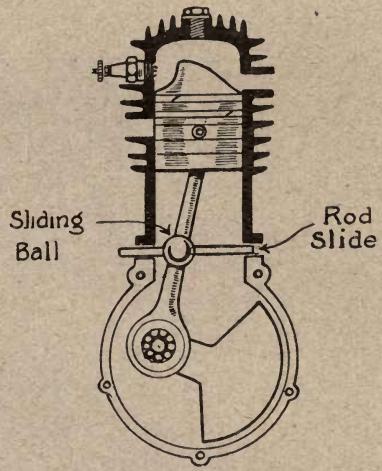
In any case, it would seem a suggestion worth adopting, that as we have crank webs, and frequently more than two turning round at very many hundreds of R.P.M., they should have been adapted to act in some way as blowers, by means of which scavenging at the end of the stroke can be obtained with pure air to clear out the exhaust and pave the way for their proper mixture with advantages which will be obvious after our previous explanations. This suggestion is illustrated diagrammatically on the previous page.

NOVEL METHODS OF COOLING AND OILING

Again, little attempt has been made to produce a double-acting engine with proper methods of cooling such as might be provided with graphite rings or graphite dust. A double-acting engine for even small sizes is far from impossible, as will be seen by a reference opposite, and it would appear that a simple method would be to arrange a slide operating round a circular connecting rod. This would still retain the Trunk piston, give a highly efficient piston pump without using mixture in the crankcase, and still enable the crank

webs to supply a little extra scavenging air if required, if the pressure was arranged to be higher than that of the exhaust.

The exhaust in any of these engines is very hot, and as an early release is necessary to enable the low inlet pressure charge to displace

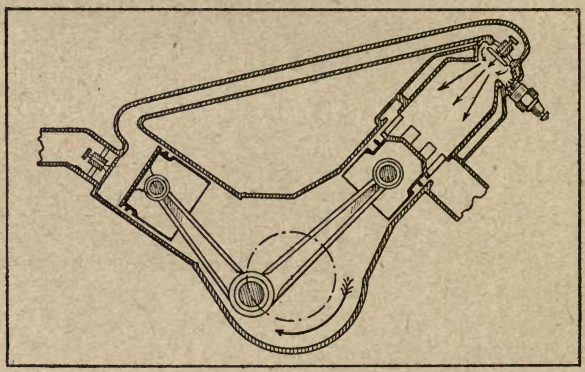


By means of a tubular connecting-rod and ball slide, the under side of the piston can supply the mixture, and the crankcase may assist to scavenge if the crank cheeks are so arranged.

the burnt gases, it is necessary to open the exhaust valve very early even at low speeds, as valve variation in timing has never been considered worthy of attention ; in the same way the inlet valve must be opened rather late, and this wastes much of the gas on the

exhaust stroke, preventing a proper charge being taken in on the inlet.

Now the use of a pump piston or some form of scavenging pump is universal on Diesel engines, which are excellent examples of



ANOTHER EXAMPLE OF TWO-STROKE PUMP CYLINDER ENGINE.
This type has been adapted to the Dolphin and other engines, and avoids expensive crankshafts, such as are necessary in the alternate pump and power vertical cylinder engines.

successful two-stroke practice, and there is no doubt that the day of the pressure-fed engine is bound to come; it will probably be two-stroke, for all two-strokes are pressure-fed in a sense, and it is more than likely it will be scavenged.

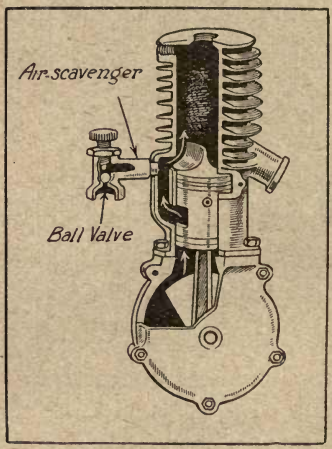
The two-stroke engine affords such a convenient method of sweeping away an instrument which is sold to provide vapour and

does nothing of the kind, that there can be no doubt that the value of a vapour engine or vapour carburetter will one day be appreciated with consequent possibilities of vapour economy and control.

These pump piston engines can be made of fairly long stroke, their piston dwell is not so important; it is not essential to make them with an absurdly short stroke, because a piston can be designed to deliver more gas than is necessary. The pump can be designed to make up for lack of crankcase volumetric efficiency, and can in turn be made to deliver the gas as and when required. The addition of valves enables an absolute control of the engine to be obtained, especially if they are made variable in operation, either separately or in connection with the throttle, as shown on the next page. It seems extraordinary that the idea of an ordinary two-stroke engine with valves operated from cams like an ordinary four-stroke has not been tried before.

THE ADDITION OF VALVES

Valves do not give much trouble, and a two-stroke engine of this type would have all the advantages of good torque, comfort, and pleasant running, whilst the addition of valves would enable proper timing to be obtained. The



The Paragon engine of 239 c.c. 66 × 70 is of the three-port type and has an auxiliary air scavenge, by which the transfer passage is filled with pure air at each up-stroke through the ball valve shown above. The exhaust gases are allowed to escape as usual, but the piston slightly uncovers transfer passage and air rushes into the cylinder from the passage before the charge. No attempt is made to cause the gases to scavenge the cylinder by special design of the exhaust passage or integral pipes.

valves could, moreover, be run direct off the shaft with very little complication, and it would seem likely that progress is likely to take place on these lines, for the mere addition of valves is no great trouble, but the addition

of separate pumps does undoubtedly reduce mechanical efficiency. It also makes for clumsiness and it is a serious complication, so that improvement, even if slightly less along the lines of thermal efficiency, might with advantage be directed to an engine in which the pump efficiency of the engine is increased and additional scavenging obtained from the crank web pump or blower such as has already been suggested and tried separately in some engines.

Valves may be added to obtain definite control of the gases and of the condition and temperature obtained by them; this would certainly be a step in the right direction, and it could avoid the use of mixture in the crankcase. Many engines have been designed in a manner to avoid petrol gas appearing in the crankcase, and if of the pump piston type this is particularly easy, because one can use the crankcase as a scavenger with pure air only, or one can use it as a blast to provide the enriching mixture whilst the pump itself carries the majority of the firing charge. The only disadvantage that this may have in a small engine is that it prohibits the use of one

general lubrication system by mixing oil or graphite with the petrol, which is quite satisfactory on small engines, but is not so good as pump lubrication to bearings and other parts, although it supplies an atomized form of oil which reaches all working parts very thoroughly, a desirable condition of affairs which might with advantage be applied to many engines in conjunction with forced feed oil.

NO PETROL "VAPOUR"

Incidentally, this system of lubrication has shown very excellently that when the petrol leaves the carburetter jet it is not in the form of vapour, for if it were, as even the *petrol* itself has to be warmed to turn into gas, the *oil* certainly is not in the form of gas; and if the petrol evaporated, as it should be made to do, the oil would separate out in the inlet pipe, for it could only be *carried* on in small globules of petrol, which in the ordinary way deposit the oil in the crankcase, and are then turned into a vapour in a more or less reasonable condition as regards its dryness fraction.

This has been actually proved by the observation of mixture whilst the engine has

been running, by means of a cinematograph with spectroscopic examination of the vaporized and partially atomized liquids, as shown in Figure C, page 123.

Another method, frequently used for marine engines, which at slow speeds has been supposed to provide a cold layer of air surface and avoid petrol in the crankcase, is that of admitting air only to the underside of the piston and carburetting it on its way to the cylinder, although certainly turbulence with rapid ignition in these small engines is more likely to destroy any such effect of stratification, especially in the use of the enriching mixture two-port engine.

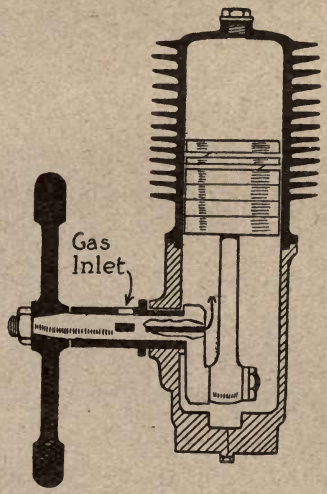
TWO-PORT ENGINES

The term two-port engine, strictly speaking, is wrongly applied. One can cut any number of holes in the side of a cylinder to let exhaust gas out and inlet in whether direct or not, but it does not make them any more than one port, and in engines of the duplex and two-port type, where we may have two working cylinders or one cylinder only, such as on

page 58 (see Paragon), with two ports, that is to say an exhaust port and a transfer port without any piston-covered carburetter valve, a valve which is usually automatic but might with some advantages be made mechanical is provided between the carburetter and the engine, so that in place of the carburetter port being closed up by the piston it is closed at the end of the stroke by means of a valve, which certainly does allow more time for suction. Now it will be quite clear that this valve can be made to operate the carburetter jet, whose opening will then depend on the engine suction.

Clearly the crankcase can be arranged to suck in the mixture in the ordinary way through the somewhat uncertain carburetter and automatic valve, or it can be arranged to suck in *air only* and deliver the same to the working cylinder in such a manner that it passes over the jet, which is kept almost closed by a small spring or weight-loaded valve. The first rush of gas will be almost pure air, and this is supposed to drive out the exhaust, leaving a cool layer over it; and yet as the rest of the gas rushes with a large

momentum effect over the jet from the crankcase when the transfer port is uncovered, it will gradually increase in richness as the



One of the oldest two-strokes was the Ixion crankcase compression engine having the usual transfer passage, but the mixture was drawn through a sleeve registering with a radial slot in the crankshaft. Most modern engines are of the three-port type, with the inlet uncovered by the piston near the top centre.

The Ixion two-stroke, like most similar engines, had a mechanical efficiency of nearly 95°.

column of air gets the heavier column of petrol or petrol and air into motion, thus providing a rich mixture for slow running if it is arranged to meet the sparking plug.

DUAL SPARKING PLUGS

Unless more than one sparking plug is adopted, however, and if the rich mixture comes in fast enough to reach the plug, it will certainly upset the layers of weak air mixture. A certain amount of turbulence is necessary or the explosion would not be over in time at high speeds, giving rise to popping and a high exhaust pressure at the end of the stroke, which should prevent development of power at high speeds. This is easily shown by means of a manograph indicator or an oscillographic indicator fitted with a wire coil in the connection, which is capable of giving very accurate results, and is not affected by harmonic wire damping effects in the pipe or port and compression volumes.

These points in connection with the two-stroke engine will make it very evident how closely the question of flow of gases can and must be studied in really scientific design. In nearly all engines, unless they have a particularly good scavenging blast, it is essential to use a deflector plate, so that the inlet gas will

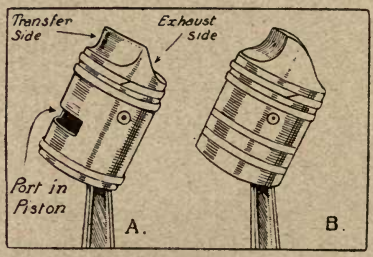
travel up towards the end of the cylinder driving out the exhaust. It needs very little thought to picture the cold gas entering into the red-hot exhaust gases with whirling turbulence and irregular expansion in all directions, generally spoiling accurate running and proper operation of the cycle.

This has been tried by means of smoke and inspection ports in the cylinder. There is little doubt that an engine without any proper scavenging system suffers terribly in this spoiling of the mixture.

At low speeds we still further reduce the amount of fresh charge, and reduce what little scavenging effect there may be by throttling the suction (weak as it is in most of these engines) and assisting the carburetter in supplying a liquid in place of a gas. The shape of baffle, as on page 66, should not be merely that of a ledge, but should be accurately designed so that the inlet gas is more or less concentrated into a steady upward stream, thus avoiding mixing with the other gases owing to their temperature and motion and avoiding sudden changes in pressure which would cause the stream to break up

and vary the position of the charge both before and after combustion.

We must not forget that all this time the piston is moving, and all care in designing these blades by making them give a small entry, by curving them centrally so that the gas will be collected, and by avoiding the use of sudden spaces (such as is done in the Scott piston), may be thrown away unless one can



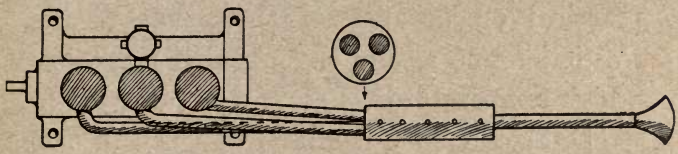
TWO-STROKE PISTONS.

A has a port in the wall through which gases pass from crankcase to transfer passage. B is used where there is direct communication between the passage and crankcase. Type A is often used on four-port engines.

give the gas an even passage as far as possible, and prevent shock eddies and sudden changes of pressure and temperature, which would spoil the evenness of the mixture, give turbulence of the *exhaust* instead of the *inlet* charge, and prevent the gases leaving the cylinder effectively, as shown in the diagram opposite.

PORT POSITION

It is only by attention to such points as these that it is possible to obtain reasonable petrol consumption and reasonably good running at slow rates of revolution. For reasons explained previously chiefly connected with those of



On all multi-cylinder two-strokes, as there is no positive scavenge, the respective exhausts must not be allowed to intermingle until the first piston has closed the exhaust port before the second exhaust port in the sequence is opened. In this manner a fly-wheel effect is obtained.

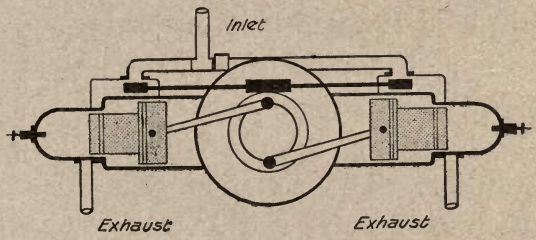
valve area, port volume, timing and pumping, and volumetric efficiency of the crankcase (if this latter is used), it is not easy to design these engines in their simplest form with a very long stroke. This is unfortunate, but, on the other hand, it prevents the piston speed approaching the highest limits, leading to bad distribution of the charge, more than is necessary to cause rapid total combustion and certainty of initial ignition at one, two, or more points if this can be arranged.

The troubles arising from a fairly high exhaust pressure or a flaming exhaust as a result of bad mixture are rather serious, for not only do they prevent the low pressure of the inlet charge effectively even partially scavenging and displacing the burnt gases, but they may even ignite the incoming mixture. The use of gauze in this connection is not always practical on account of the effect of its restriction and also of the fact that it attains a high temperature.

The Scott engine has been designed in one form with oscillating or semi-rotary cheek valves without any compression space in them; this does away with transfer jointing and gauzes, but needs care in balancing on account of its somewhat high weight. Two-stroke engines on this account will not usually run at very high speeds whilst giving any reasonable power, although the compounding of rotary valves with the ordinary type enables better results to be obtained if the added complication is not mechanically serious.

This has not only been done in the Scott engine, but quite recently in the M.I.P. horizontally opposed two-stroke, which has

been produced to represent a type of engine which may become common on account of the excellent balance obtainable; the slight off-set of cranks which is necessary with direct driven rotary valves or eccentric driving sleeves and piston valves is not excessive, and the use of a pump, or incorrectly named



The M.I.P. horizontally opposed two-stroke can be perfectly balanced, though the torque is that of a single. Mixture is admitted to the working cylinders by rotary or piston valves, whilst the crankcase compression is used for scavenging only.

"differential" piston, does away with the disadvantages of lack of full delivery from the crankcase. There is also the possibility of using the crankcase oil to scavenge the cylinder before delivery from the pump piston.

A crankcase blower without any other form of valve is more likely to make its mark in the future, whilst quite insufficient attention has been paid to the reduction of crankcase volume by the addition of wood crank cheeks, together with proper designing of the connecting rods, which can very easily be combined with a slide. This slide prevents over lubrication of the cylinder and largely increases the pumping efficiency of the underside of the piston, still leaving us the chance of using the blowing effect from the crankcase with its help for lubrication. See illustration, page 53.

The use of rotary valves greatly assists the design of any kind of engine, but they are difficult to keep in good order even when protected by pump or working piston from high pressures and temperatures. Worse than this, unless they are two-ported from the centre space (which is often required for water cooling), or unless they are balanced and driven at high engine speed, it is difficult to drive them fast enough really to obtain rapid valve opening when needed.

Variable timing of valves would in this connection have received more attention, were

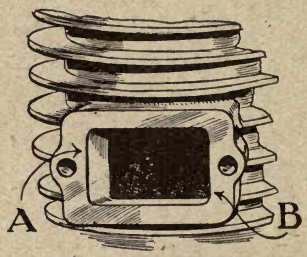
it not for the advantages of simplicity for the cheaper class of automobile work. The scavenging of all these engines is an extremely important subject, and in this country it is surprising what little attention has been paid to it. Double-acting engines are easy to scavenge because one side of the engine can be used to supply air, but in the ordinary case the designer of small two-stroke motors does not seem to realize that with large power plants it would often pay to incorporate a pumping or scavenging cylinder, simply to get rid of the burnt gases, increase the thermal efficiency, and reduce general wear.

Here, again, the space occupied by the extra mechanism is of importance, and there are many cases of engines on the market which would benefit largely by the use of larger port areas, but which would slightly prevent the clean outside appearance of the engines and have therefore been rejected by their designers.

The more impulses per revolution the more we approach the turbine, in which overheating troubles are supposed to come to a height, and this is simply because the fuel has not been treated as a chemical which is giving

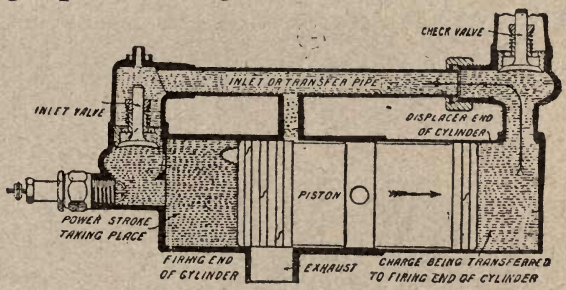
its energy off in the form of heat; there can be little doubt that the future will bring forth some design to overcome this difficulty by the use of cooling material in the burning jets.

There is no reason why any number of ports should not be used in the cylinder of an engine, and it is somewhat surprising that in conjunction with scavenging designs previously applied to engines, an exhaust release should not be found useful for three, four, and five port engines if necessary. In cases where the crankcase is used to "carburet" the mixture, as must of necessity be the case with most of these engines, the larger the area provided, so long as interference in the gas is not experienced, the higher is the possible efficiency of the engine in almost every direction. It is vitally important to provide smooth and clean ports.



Clean port edges at A and B are essential.

Whilst on the scavenging question it is interesting to note how little attention has been paid to silencing, with which it is closely connected. Large numbers of two-stroke engines are badly silenced, and this is because their designers realize the fact that these small high-speed multi-geared units, which will in



TYPES OF TWO-STROKE ENGINES.

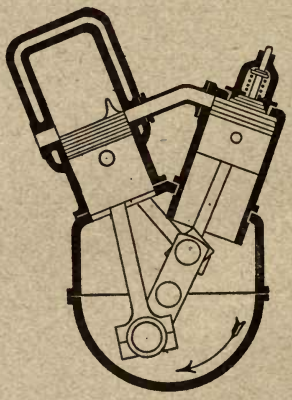
The Wooler Engine, which has a double piston.

Mixture is drawn through the check-valve on the up stroke, and passed through the transfer pipe on the firing stroke. The connecting rods are attached to a projecting gudgeon pin.

future become so popular, are liable to be called upon to run under very different conditions, so that absolute clearness of exhaust port edges and pipes is of extreme importance; all back pressure also must be avoided.

Once the fact is grasped that silencing an engine consists, or should consist, in applying a fly-wheel effect to the gases, it would be realized that what has got to be done is to

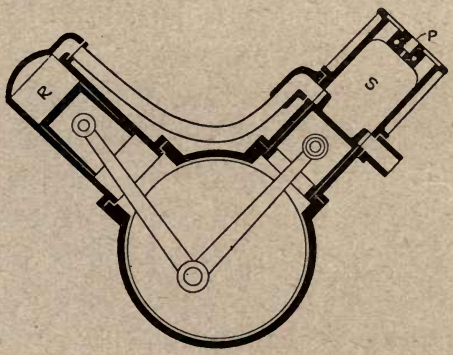
arrange an expansion chamber together with a pipe in which the momentum of gas will be sufficiently large to draw out the burnt mixture as it is produced in the engine. By such an arrangement as suggested on page 65 the heat of the exhaust gases is made use of to scavenge the engine, and is not all uselessly dissipated into metal parts and the atmosphere; the pressure against which the exhaust takes place can frequently be actually reduced below



The Appleton Engine has been made in two and four cylinder types, and the pump cylinder is arranged so that there is a tendency for a layer of air to separate burnt and fresh mixture. Unfortunately on small high-speed engines mixture, colour, and temperature examination by steam injection or thermometer show little stratification to exist.

that of the atmosphere, and at a time when this pressure is of greatest moment.

This is quite different to baffling the gases and allowing them slowly to escape; the outlet should be at as near an equalized pressure as possible, as in the case of any other engine. The fouling of exhaust ports and



In the Le Pape Engine the pump and working cylinders are both controlled without mechanical valves on the ported system. The cylinder is charged with air, and liquid petrol is injected by a capillary tube filled from a pump. A sparking plug is used as usual, but the quantity of fuel injection cannot be accurately varied. The capillary tube is usually of platinum, and is bolted into the passage P, by a block which carries the lead from the pump. The pump is not shown, but is driven off the engine as usual. R is the pumping, and S the working, cylinder.

silencing brings up the question of lubrication already touched upon in the description of different types of engines.

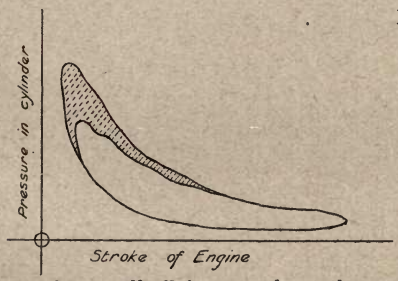
The lubrication of two-strokes does not differ from the lubrication of any other engine, except in the fact that they may rise occasion-

ally to a slightly higher temperature. When the number of impulses approaches the infinite, as in the turbine proper, then may be the time to talk about the use of graphite. But mixing the oil with the petrol is really a substitute for a pump to introduce the oil at every other point of pressure, as has been proved by actual practical demonstration by the spectroscope applied to an engine fitted with a glass inlet pipe. The oil is taken up by the petrol, which does not evaporate until it reaches the cylinder, only partially vaporizing in the crankcase.

This serves to show of what little use is the carburetter as a vaporizer without the crankcase, and incidentally how the oil is burnt up as fuel so as to raise the mean effective pressure. If the petrol turned into gas immediately after leaving the jet, it would leave the oil deposited in the inlet pipe, which it does not do, and it has been actually possible to watch the petrol and oil globules passing up a pipe into the crankcase preparatory to their complete atomization and consequent volatilizing (see page 125). This leads to considerable portions of the oil being

burnt; but there is no reason why it should not be so treated if any waste heat can be used up to deal with the fuel.

Gas is practically never supplied to the cylinder of any engine, it is really only a wet vapour; but in the two-stroke engine there are possibilities of the crankcase being supplied with the wet gas and the cylinder with true vapour. Nothing is to be more desired, and nothing can be more hoped for, than the fast approaching time when all engines will be dealt with as regards their inlet supply by induced feed. All two-strokes are really forced induction engines, and it is only by repeated experiments that new designs can be produced successfully and each so-called fact brought to light.



In a two-stroke engine the main effective pressure is reduced by the presence of burnt gases: if these are removed by scavenging, the pressure of the explosion rapidly rises as shown by the shaded portion of the diagram. A real gas would often explode too rapidly for overall efficiency, and yet the vaporization of liquid particles greatly reduces the thermal efficiency of the engine.

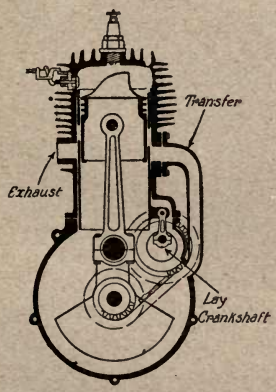
It would be desirable to refer to engines in which the feed is by direct pressure as *Positive Feed*, keeping the expression *Forced Induction* for engines in which the delivery feed remains considerably above atmospheric.

TIMING OF PORT COVERING

In all engines where the mixture is fed in under pressure the question of timing is bound to be of great importance, and the addition of some kind of valve to the ordinary crankcase compression engine becomes almost a necessity for any engine dealing with fuel at a really high effective pressure. In the same way it becomes necessary to use ports of large dimensions in order to secure rapid *and* free entry and exit of the gas. As the size of these ports is bound to alter the timing of the engine, one is faced with the necessity of rather adding to the complication of the engine in order to enable the inlet gas to have a sufficiently high entry speed, not only to give scavenging without mixing, but to secure the gas reaching the portions where the initial explosion can take place.

INTRODUCTION OF VALVES

The use of valves, whilst apparently a very easy way out of so many engine difficulties, is not a step to be taken without great consideration, and it would seem probable that anything which does away with the great point of simplicity has not everything in its favour, because the repair bill of any engine is usually far larger than that of its actual running costs. Large numbers of engines have been introduced making use of different types of valve gear which attempt to deal with any or all of the problems upon which we have already touched.

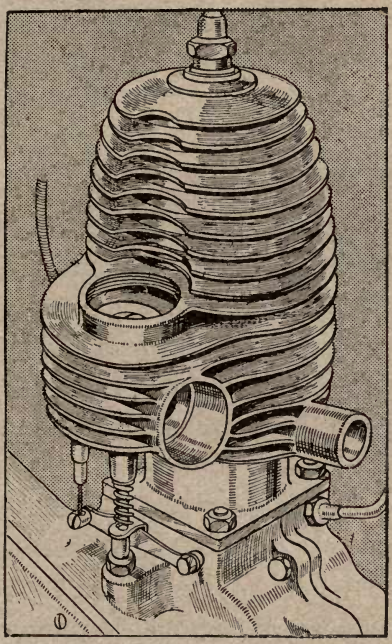


A valve-controlled sleeve (or sleeve and poppet) valve can be used to control effectively the inlet and prevent admixture. This in conjunction with the crank well pump or blower of, for example, the N.E.C. or Roots type, may lead to a satisfactory reduction of fuel consumption in commercial two-strokes. The sleeve is operated through a lay shaft driven by chain off the main-shaft, and controls the inlet. The slight up and down movement of the sleeve causes it to register with the ports.

One of the most objectionable points about the ordinary four-stroke poppet valve engine is that of the springs in the valve system; for whilst the valve is wonderfully efficient as regards its opening and closing, it is usually bad as regards the mechanism employed and the strains of working just before opening and just round about closing.

It is possible that these points may be done away with in combination with the sleeve engine, and some mechanism will be employed which will positively operate the valve: such as that of a spring valve and eccentric. The poppet valve is usually far more efficient than the sleeve, but the operating mechanism is very bad. The application of an ordinary poppet or other valve to the two-stroke engine principle, running at engine speed and possibly engine operated, might make for great efficiency and avoid the need for constant cleaning, for which so little convenience is provided. But these valves should certainly be force closed, and their operation should not depend on springs and on bouncing of valves

when so many hours have been spent in cam setting and months in cam design (see below).



Cylinder of Quadrant Two-Stroke, showing long-stroke cylinder and mechanically operated valve to prevent exhaust mixing with inlet during transfer. Engine 374 c.c. 70 × 100 mm. These engines are not at present on the market.

These points are not mere imagination, the bouncing of valves not operated by force-closed mechanism has been actually observed

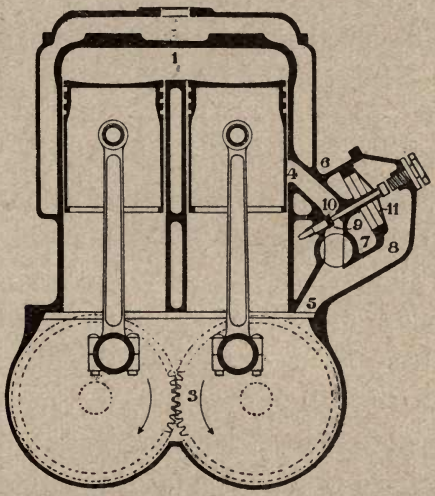
by means of relay or cinematograph mechanism, and it is such that in combination with the absurdities of imaginary carburation and bouncing needle valves it reduces accuracy on the commercial engine to an entirely negligible quantity.

ADVANTAGE OF SIMPLE VALVE GEAR

Most of these points go to prevent the development of engines on more complicated lines, although there is no doubt that a simply controlled valve gear may be found advantageous in the case of car engines and later on smaller plants, where we build the engine for the sake of its even torque and not for the sake of its simplicity or cheapness. Large numbers of different engines have been constructed embodying these points. We have had engines in which to prevent four-stroking—when the entry speed of the gas is not high enough to displace the hot exhaust—the deflector plate has been carried in the middle of the piston and the gases passed up it into a bulb built at the top of the combustion chamber to accommodate the plate. This breaks up the combustion chamber and

therefore is not in every way a step to be desired.

We have had the two-port engine with the valve on the carburetter side. We have the duplex engine with poppet valves, in which one cylinder set at an angle acts as a pump to the working cylinder. This was successfully tried long ago.



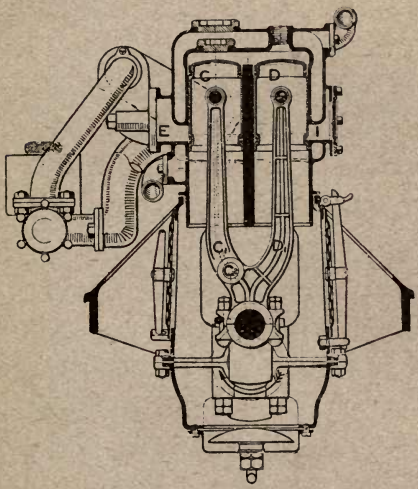
The unit combustion space engine in another form, in which the mixture can be regulated before actual firing without any carburation lag, owing to the provision of an automatically operated needle valve. This gives a light and quite efficient engine, but it is clumsy for high-speed engines of more than one unit. (1) Single combustion chamber and crankshafts geared together (3), air enters by ports (7) and (8) through air valve (11) in carburetter (6). This valve has a long stem (10), with needle valve at end, seating into petrol jet (9), which, on lifting, admits petrol into surrounding chamber. When pistons descend, the air in crankcase is compressed till inlet port (4) is uncovered by pistons, when air takes up the petrol in jet chamber and enters cylinder.

The two-piston common combustion chamber type of engine at present is built in twin-cylinder sizes only. The two-stroke engine, or to be more definite the one impulse per revolution engine, does not necessarily employ either crankcase compression or imply great simplicity. These points should not be considered until afterwards, even if borne in mind during design, because there are great possibilities with engines in which the gaseous mixture is led in, carrying with it air for combustion on the injector principle.

There are many means and many combined methods of operating pistons, slides, crank cheeks and connecting rods in such a manner that we can fill our cylinder with gas when we want it, so let us not always be considering too many details in the beginning, for like the valve whose inertia, both gaseous and of the valve effects the possibility of pure operation to any of its parts, so is it difficult for us to ever bring out a new design without considering first its broad possibilities.

It is quite extraordinary how few experiments have been tried on the subject of two-stroke engines, forming as they do the stepping

stone between the occasional impulse engine and the turbine, and it is only to be hoped that some of these notes will have the effect of stimulating readers into realization of the value of the principles at stake.



TYPES OF TWO-STROKE ENGINES: THE LAMPLUGH.

C and D pistons coupled up to a single crank-pin by means of connecting rods C^1 and D^1, the former being hinged to the latter at the centre C^2. The combustion chamber is common to both cylinders. The exhaust port E and inlet port I are of the same width.

By this is not meant the mere different construction of standard engines, such as the two-piston type, in which the compression is higher in the fuel charge or air charge cylinder than in the actual working compartment. These engines were at one time quite popular for lighting work, but are as yet of no great value for automobiles.

WHERE DESIGN WILL ADVANCE

The unit construction of multi-cylinder two-strokes with speed gears combined has yet to receive proper attention, as also has the long stroke two-stroke, which is perfectly practicable once the volumetric efficiency of the pump side has been raised in some of the ways suggested. This is far more important than a mere alteration of the number of parts or the use of separate valve gears to control their opening.

The engine speed variable valve possibly combined with water injection to the piston and walls and not to the gas is also another form requiring study. Some of these engines are shown in the illustrations in this book, and show the means some designers have endeavoured to adopt to ensure fresh gas reaching the plug. This is quite as important an item as that of proper scavenging, and one which is closely connected thereto.

The Ricardo engine is a very pretty example of a separate cylinder V-pump cylinder engine. It rather jars to see a cylinder only pumping, and makes one wonder if the four-stroke with

an equal number of cylinders is not as good, for at least only one cylinder is required; but for all that it is good and, as will be seen from the sketch on page 39, it is quite simple.

The simple three-port three-cylinder two-stroke unit has also not been really appreciated; and on the multi-cylinder engine such directly accurate means of directing the mixture by separate valve gears is not absolutely essential unless thermal and volumetric efficiency is required. The fact that these are nearly always lower than those of corresponding four-strokes shows how much more important are the other characteristics—simplicity, good balance, and even torque—with which we have already dealt and which may bring these engines into favour for large cars and almost every form of power-producing plant.

A vast amount of improvement will take place with this type of engine, for its value is difficult to overestimate; it is helping thousands to enter the motor industry both on the manufacturing and on the user's side, and the public is very apt to class all engines together and imagine they have all had an equal amount

of work expended upon them, when nothing is further from the truth.

WHERE DESIGN FAILS

The research and real knowledge that is necessary for the design of an engine belongs to but a few, and many engines bear evidence of this fact. The two-stroke unit will certainly give us the multi-impulse machine and the continual impulse engines which are the power plants of the future. They will be simple, cheap—perhaps not cheap to run at first – they will be light and pleasant to the thousands who have not yet realized what this can mean for them. Most engines now bear the stamp of the four-stroke in their design; they are heavy, and considering the low pressures attained in the cylinder they are unnecessarily heavy, whilst no one seems to have realized how these pressures can be varied by the smallest alteration of the actual gases which are working. A few of the most improved designs and points only have been touched upon; for the subject is one of the broadest it is possible to conceive, and it can only be

treated successfully by originality and imagination.

The mere repetition of external details and data cannot benefit anyone, neither can it lead them, however unconsciously, to the advancement which is our all in all.

Some notes on the use of petrol and carburation will be found elsewhere ; no attempt has been made all through to reproduce extracts from makers' catalogues or to deal with any so-called problems by rule of thumb methods.

The object has been to explain the why and wherefore of the situation ; once this is mastered it is easy to make suggestions and easy to grasp the working, faults, remedies, and above all the *best* possibilities of any engine, either built or to be projected. A study of the numerous diagrams of engines in these pages shows the general trend of design very effectively.

TWO-STROKES AND FORCED INDUCTION

It is not possible to cover the subject of two-strokes at all thoroughly without briefly explaining the meaning and objects of forced induction. This phrase is somewhat loosely applied, however, and has been used as an excuse for many notable performances of different engines. This only goes to show the importance of really obtaining the cylinder full of mixture, because the idea of forced induction primarily suggests the obtaining of a proper charge of combustible mixture quite apart from atmospheric and other conditions.

Forced induction in itself simply means that the mixture in the inlet pipe, instead of being usually slightly below atmospheric pressure, is above atmospheric, and therefore, nominally speaking, every two-stroke engine is operated by "forced induction," and were it not for the exhaust displacement and pumping inefficiency so often experienced, this would be an extremely good argument in favour of the two-stroke type of construction.

Forced induction, needless to say, is usually taken to mean the feeding of mixture to the

engine at some *appreciable* pressure such as twenty or even several hundred lbs. per sq. in. In engines such as the N.E.C. a fan is used for driving the mixture into the cylinders, where it is compressed by the piston in the ordinary way, and in this case the fan is, as has already been explained, utilized to drive out the burned gases of the previous charge, or else the lag of an automatic valve in the inlet system may be used to scavenge the engine as well as to supply or distribute its mixture.

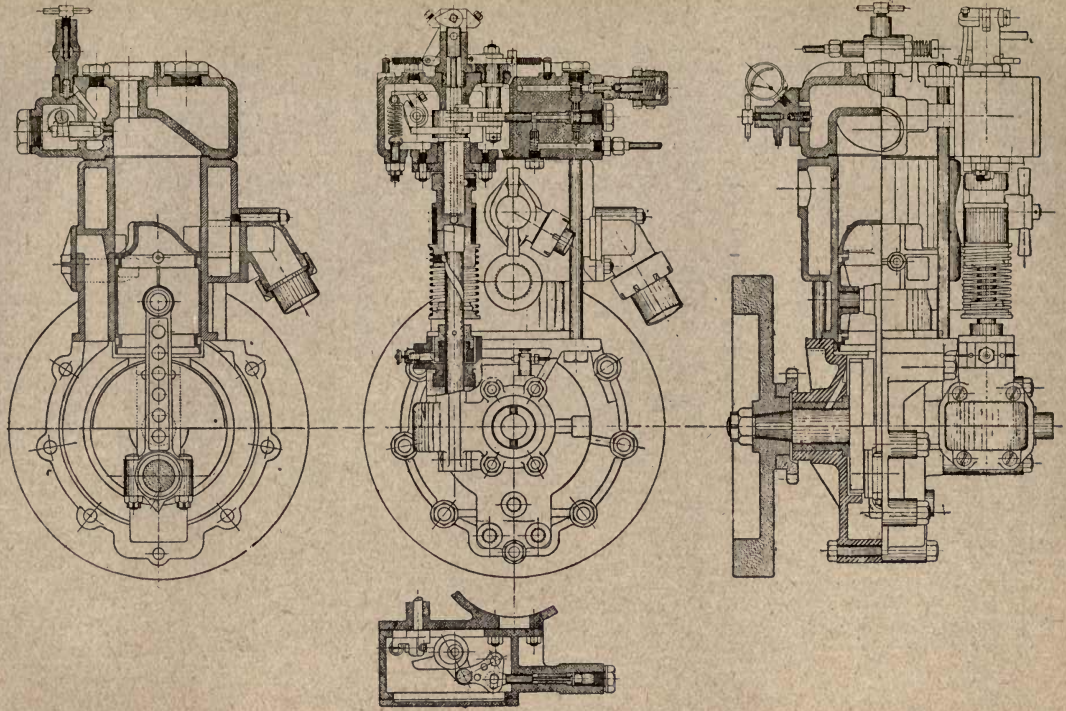
On the other hand, there is a type of engine referred to as "forced-fed," in which the combustion takes place during or before the feeding in of the mixture. This, in conjunction with pump scavenging or pump-fed two-strokes, has sometimes been arranged so that the working cylinder compresses a very weak charge or even a charge of pure air. Then another similar cylinder having sucked a rich mixture from some sort of carburetter or heavy oil vaporizer, is allowed to inject this fuel into the air, causing the explosion or heat expansion by its own contained heat. In such a case liquid fuel is usually necessary,

because unless the injection takes place with considerable rapidity the resulting expansion may cool the local mixture below the firing point, and yet if the mixture is all injected at once it may be necessary to do so in a liquid form to prevent an unduly rapid rise of explosion pressure.

In many cases of engines referred to as "Semi-Diesel" the fuel is allowed to run or inject on to a heated bulb or even a hot valve cap, where it is vaporized and burnt. In many of these types of engines, especially of large power, it is usual to inject a stream of water on to the parts exposed to rapid heating.

It should be carefully noted that such water injection should take place as a liquid stream on to the hot metal as the heat should be absorbed from the *metal* by vaporization of the water; and not by a water-drip or by cold steam being injected via the mixture, where it would cool and reduce the initial explosion pressure, instead of absorbing waste heat from the walls and maintaining pressure towards the end of the firing-stroke.

It is important to remember that the question of a forced fuel feed or forced

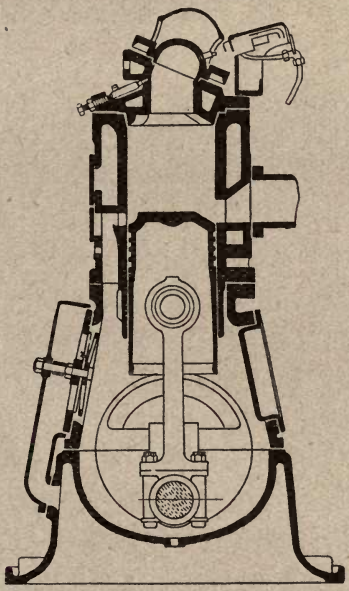


THE LOW ENGINE.

induction has nothing to do with the primary cycle of engine operations, whether it is for two or even six-stroke. The idea of forced induction is usually taken to imply a feed pressure as regards the fuel, if not the air, of an amount greater than that of the compression; because the fuel is naturally taken up and taken in during the compression stroke, if the latter is of high enough ratio to cause self-ignition. In this case a pressure of 200 or 300 lbs. per sq. in. is perfectly practicable without any undue signs of dissociation in the firing gases.

This principle has been exemplified in the Low engines, which have been built not only to obtain the fuel consumption advantages of high compression, but also to make use of waste heat to prepare the fuel under pressure and then to fire the charge more or less gradually, according to the rate of fuel admission in conjunction with a constantly operated spark or other means of controlling the primarily entering gases to the combustion point. This is of course perfectly simple, in spite of the apparent complication of the idea, and it will be seen from the diagram that it

does not lead to any great difficulties in construction other than that of a valve gear to stand up to the load of pressure and consequently of temperature.



CROSS SECTION OF PETTER SEMI-DIESEL TWO-STROKE.

This engine is a good example of the heavy oil two-stroke. The oil is injected on to the hot head at about 700 lbs. per sq. in., and is immediately part vaporized and burnt.

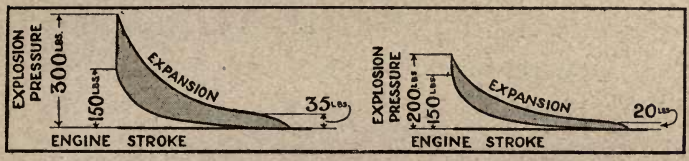
DIESEL ENGINES

It is very common in many branches of engineering to quote examples of particular power plants, and on the assumption that they are large and give good results, it is frequently suggested that smaller types will be equally satisfactory. Now whilst the principle of this cannot be entirely commended it is possessed of considerable truth, and it has been exemplified to a remarkable extent in the two-stroke Diesel and other forms of two-stroke scavenging engines.

In the Diesel engine (of which a rough diagram of a representative type is given, together with a drawing of what is known as the injection valve) the cycle of operations is extremely simple and does not differ in the four or two-stroke models, except in as much as the number of explosions per revolution of the crankshaft.

The Diesel engine is constructed in a very

similar manner to the ordinary type of internal combustion engine, but owing to the heavy nature of the explosion it is constructed



WORKING LOAD DIAGRAM. HALF-LOAD DIAGRAM.

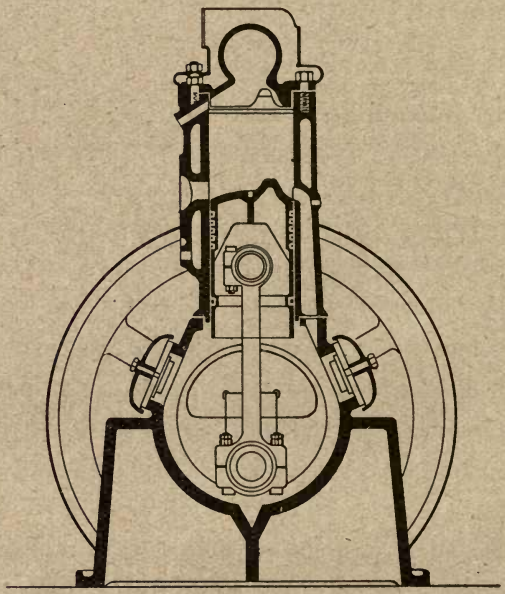
TWO-STROKE SEMI-DIESEL CARDS.

considerably more strongly. In the working cycle of a two-stroke Diesel, the piston when descending the cylinder draws in a charge of air only, at ordinary pressure and temperature. This charge is then compressed, and at the top of the stroke, or when the exact firing moment is reached, liquid fuel is blown into the compression air through an injection valve by means of air at a considerably higher pressure than that of the compression of the engine.

No other ignition apparatus is required than the natural heat of compression. In engines where the compression is 200 lbs. per sq. in., the injection air which blows in the fuel will probably be at a pressure of 600 or 800

lbs. per sq. in. In this case the air is also used frequently for starting purposes, the pressure being maintained by pumps driven off the engine and the air stored in steel cylinders.

Naturally the greatest care has to be taken to prevent oil mixing with any part of this compressed air, or else explosions may result.

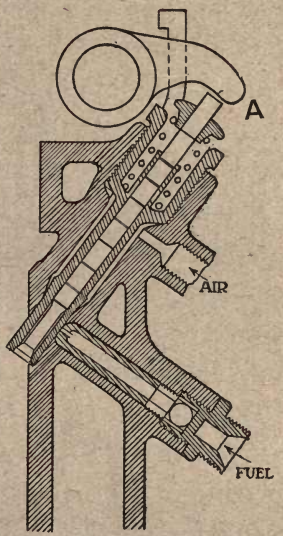


CRUDE OIL INJECTION ENGINE OF THE DIESEL OR SEMI-DIESEL TYPE.

This can be used with the ordinary Diesel injection valve, either air or full pump operated.

Indeed, it is quite common for Diesel engines running on oil fuel, on account of the high temperatures reached, to develop small cracks in the cylinder head and piston, although these do not necessarily destroy their efficiency.

On the Diesel firing-stroke (during the first portion of which the fuel injection is taking



FUEL INJECTION VALVE FOR CROSSLEY ENGINES.

This type of valve is used in Diesel Engines, also where air pressure injects fuel into a charge of compressed air in the working cylinder, enabling a high and effective compression to be used. Air is compressed into containers which are connected to the point marked "air." The valve A is operated from the camshaft, and so timed that when the piston has compressed pure air drawn in on the suction stroke, the valve A opens and the air rushes past the fuel pipe and sprays it into the highly compressed air.

place) the explosion pressure is naturally very high, being frequently three times that of the compression, and the exhaust is consequently often relieved by means of auxiliary ports.

Now in both four and two-stroke Diesels, owing to the method of ignition, it is very essential that the cylinder should be properly scavenged, and it is almost impossible to run an engine satisfactorily without a good blast of scavenging air. The scavenging air need only be at a pressure of possibly 10 lbs. per sq. in., or sufficient thoroughly to drive out all burnt gases; and as the running of a Diesel engine is not particularly smooth, it is of great advantage to have an explosion every time the piston reaches the top of its stroke. This is particularly the case as the amount of liquid fuel (unlike engines which convert it into vapour first) cannot be easily controlled. These reasons have all helped in the adoption of the two-stroke principle to such an extent that this type of engine seems likely to carry all before it in both marine and other heavy generating work.

As far as the motor-car engine or motor-cycle engine is concerned, it seems more likely that the principle of making use of waste heat or other methods of vaporizing the fuel will be adopted in order to obtain a more delicate control. This in conjunction

with a separate carburetting arrangement (if necessary to supply the mixture) might give us a form of high-compression engine of great economy and also available for compression flexibility.

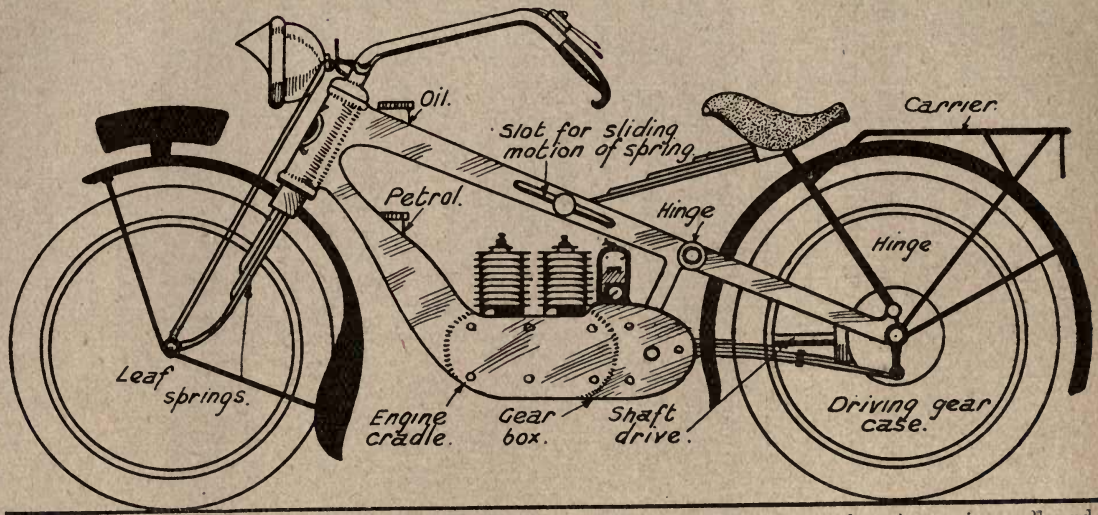
Quite a number of Diesel engines have been built for automobile practice of the full Diesel or Semi-Diesel type, and one or two of them on the two-stroke model. These engines have usually been fitted into fairly large chassis, and whilst of use for lighting and some commercial purposes, they have been so uncontrollable (except in the cutting out of one or more cylinders) as to be almost useless.

There can scarcely be any doubt, however, that the high compression, forced feed system will soon be very much to the fore, because the carburetter has always been one of the most unsatisfactory parts of an engine. This is particularly the case in two-strokes, not to mention the dependency of the ordinary engine upon the ordinary small atmospheric pressure available to push the mixture into the cylinder under the influence of the piston suction.

UNIT CONSTRUCTION AND MULTI-CYLINDER TWO-STROKES.

The small two-stroke engine has been exploited chiefly as a single-cylinder engine, and has varied largely throughout different types, chiefly in lubrication systems and the number of ports employed. Were it not for the various ported methods of obtaining mixture from carburetter and crankcase and the number of transferences necessary, nearly all motor-cycle two-strokes might be treated similarly, although the Scott, which was one of the pioneers and one of the finest two-strokes in existence, is an exception.

The two-stroke self-contained unit giving us engine, gear-box, and clutch in the one block casting, whether the gear be epicyclic or sliding, has yet to be exploited to any extent. It would seem desirable that attention should be given to the type of two-stroke unit which has two or more small cylinders. Some method of raising the ordinary crankcase compression, such as have already been



A sketch showing how a Two-Stroke Engine can make up into a bicycle of great neatness by using engine cradle and frame of U girder section in one piece.

described by pumping arrangements in the crank-case, fans, or blocking of the crank-cheeks, is almost essential to economy.

The motor-cycle world in particular offers every opportunity for a small machine having perhaps a two-cylinder unit stayed longitudinally and totally enclosed with gear-box, starter, and lighting arrangements, all contained in one compressed U-shaped girder; with tanks of every kind, also made of compressed steel-aluminium, and sprung fore and aft. The well-designed two-stroke engine does not always need quite so much gearing as the four-stroke, and it might therefore be possible to incorporate a form of variable worm or roller drive.

Such a unit and machine can be made of extremely clean outline, as is shown herewith in diagram, and at the same time it would lead to cheapness, ease of construction, erection and maintenance.

CYCLECAR TWO-STROKES

As an example of a particularly useful application of the two-stroke engine, an illustration will be found herewith of a three-cylinder cyclecar unit of 1085 c.c. It is strange that more attention has not been given to cyclecars, where above all one requires simplicity and cheapness together with lack of vibration and smooth running.

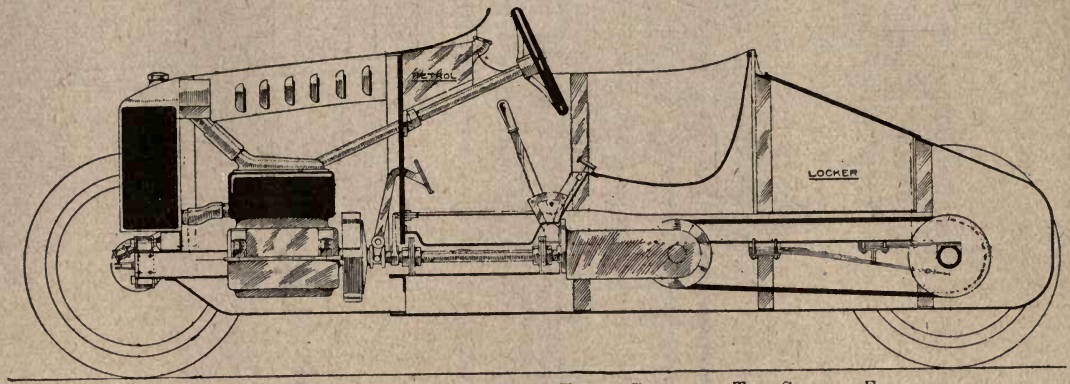
The unduly noisy and ragged running engine is responsible for many failures in small car and cyclecar designs, and one has only to picture the pleasant running of a single-cylinder motor-cycle two-stroke engine and then to imagine three of these bolted together, to conceive what a delightful unit would be obtained. Smooth running, splendid pulling on top gear, simplicity, maintenance of tune and cheapness can all be had ; whilst one of the greatest troubles of the small two-stroke engine—namely so-called four-stroking, due largely to bad cooling, bad carburation, and faulty port and silencer arrangements—can be avoided when one has the ample

space which it is easy to find on the four-wheeler.

Some notes of details of one of these three-cylinder units, with some of the main data worked out, are shown on the accompanying pages as being of interest to those who care to follow up the matter from first principles, beyond which it is not possible to go in the short space available in a non-technical book.

The vast majority of two-stroke engines would have been improved by a knowledge of indicator work on the part of their designers, but this unfortunately has been difficult to obtain owing to the fact that with the exception of the magnetic and oscillographic manograph it is not practicable to obtain "cards" (as indicator or pressure diagrams are called) at high speeds with any ordinary form of indicator.

The type which should be used is that in which the stroke is given by a synchronous motor running in phase with the engine and the pressure by a reading of the current passing through an oscillograph and generated instantaneously at any point by a diaphragm



DESIGN FOR A CYCLECAR FITTED WITH A THREE-CYLINDER TWO-STROKE ENGINE.

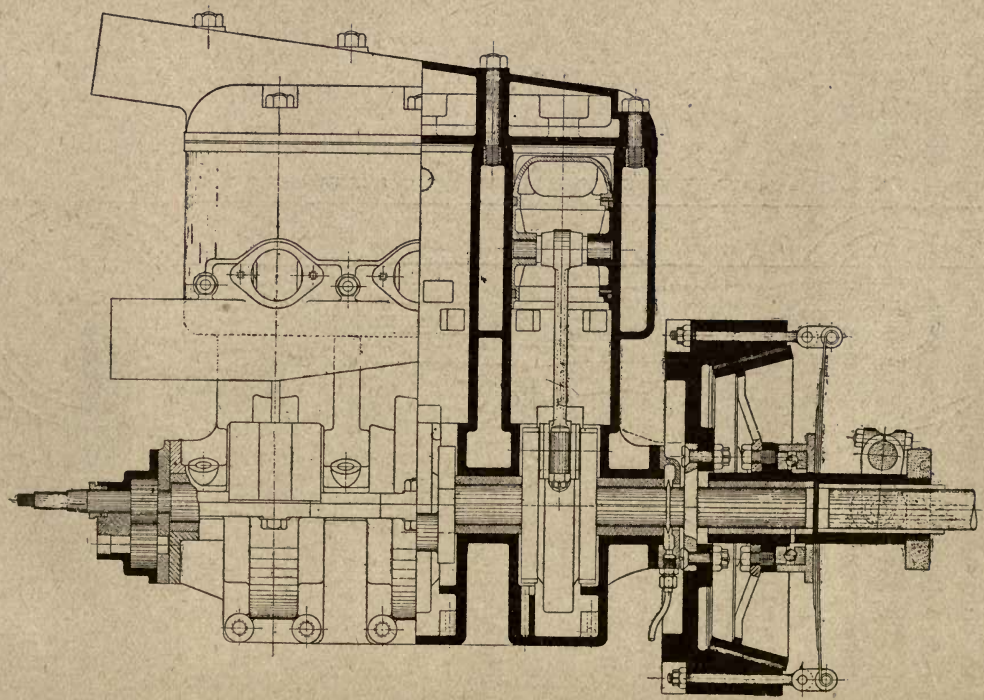


Diagram of Three-Cylinder Unit

in conjunction with an electro-magnet and controlled by the pressure in the cylinder.

The two-stroke engine is bound to make its mark wherever simplicity, cheapness, good acceleration, and general handiness are concerned, but it must not be forgotten that at present two-strokes are not commercially as efficient as the four-stroke, neither have they reached by any means the same perfection of development, and it is only hoped that some of these suggestions may help readers to form their own ideas. Indeed, not a few of them are already becoming everyday practice.

TWO-STROKE LUBRICATION

In the ordinary way the lubrication of a two-stroke engine need not differ from that of any other type except possibly for the reason that a two-stroke engine often runs at a rather higher temperature than the four-stroke, and, therefore, in consequence needs particular care. It must be remembered also that any free oil and indeed any thin oil in the crankcase will probably affect the mixture, and, therefore, in addition to its temperature being raised it will be sprayed into the compressed charge and thus burnt.

The two-stroke engine, however, maintaining as it does a more constant direction of pressure throughout the connecting rod's big end and gudgeon pin bearings is very easy to deal with when once these points have been grasped from the non-technical standpoint.

Lubrication in principle is perfectly simple, being really a means for supplying a continuous new surface at the points where rubbing

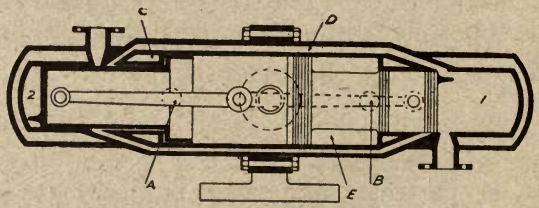
would be taking place between metallic surfaces. This is accomplished by introducing small rollers of oil quite apart from the type of bearing used, and these small globular particles of oil cannot be driven out unless their form is destroyed by excess of pressure put upon them. The surface tension of these globes together with their molecular formation is responsible for their lubricating properties. Once this is remembered the reasons which will be dealt with following for the separate use of oil will be readily understood.

Oil, like everything else, is far from being everlasting in its construction and therefore has to be removed after it has been subjected to any particular amount of rubbing. Almost any substance can be used for lubrication; air and petrol are both lubricants, and it is only a question of the pressure of the lubricant being sufficient to keep the surfaces apart, which is one of the reasons why oil should not be used at atmospheric pressures only, for its pressure under load is bound to increase.

Air alone is quite a good lubricant under sufficient pressure, and air and oil is better

still, just as two perfectly plain surfaces will float on each other owing to the pressure of a film to keep them apart.

There is very little difference in the case of lubricating the two-stroke engine from the ordinary four-stroke engines, except as regards the total amount of heat generated both by explosion and by the residual gaseous and mechanical friction per crankshaft revolution, and it is therefore advisable to make



TYPES OF TWO-STROKE ENGINES.

The Victoria Engine could be constructed either one or two crank, but was run with one crank pin only. No valves were used, ordinary port transfers being employed. In the illustration No. 2 cylinder is firing. Mixture is drawn in through ports A and B. Mixture in space C is transferred through D into No. 1 cylinder, and E is filled with mixture.

better provision for cooling and lubrication in the two-stroke design, especially if air cooled. The two-stroke engine usually runs at a higher temperature, although the maximum pressure in the working cylinder is less,

on account of the lesser time available for radiation.

Were it not for other causes, such as gas refraction and expansion, the hot cylinder engine would be more efficient; but it is difficult to obtain a high compression pressure or a big bore stroke ratio (even in engines which are not pocketed), because the larger motion of the piston and the separation of ports necessary to obtain good timing is liable to cause whirling in the entering gases, and consequently mixing with the exhaust and loss through the exhaust port.

MIXING OIL WITH THE PETROL

It is perfectly practical to lubricate all these engines in spite of these difficulties by passing oil into the inlet pipe, but no form of "petroil" lubrication such as will be described in these experiments is so suitable for every part of the engine as is forced feed.

A combination of the two in conjunction with a mechanical arrangement for regulating the quantity of oil represents one of the most simple solutions. The value of "petroil" lubrication is easy to see by the improvement

obtainable by dissolving lubricating oil in the fuel, by the proper use of graphite.

OIL SEPARATION FROM MIXTURE

The two-stroke engine is extremely old in its design and it is likely to outlive the four-stroke model. Now as the majority of engines have been up to the present fitted with crank-case compression it is only natural, as the oil and petrol vapour are both entered and mixed in the same compartment, that the effects of mixing the fuels should have been tried and found so successful, particularly with small engines, and without trouble from undue deposition.

Even the use of graphite in the oil may be beneficial without undue separation so long as the lubricants and fuel are not acid in nature.

The question of lubricating through the carburetter or "petroil" lubrication is very much bound up with that of lubrication itself, because should at any time total vaporization take place it would appear that the oil would merely be burnt up and act as a fuel of higher carbon content in place of separating out in the right place, and just where wanted,

due to local pressures causing the correct amount of deposition.

Petrol is simply a hydrocarbon containing hydrogen and not oxygen, but many lubricants are not mineral oils but are vegetable or organic and therefore contain oxygen also.

These points must be clearly remembered, for whilst nearly all these oils are good lubricants they differ in the means required to use them successfully; and the process taking place upon the introduction of oil to an engine should be carefully considered, especially in conjunction with engine speed and power. When the engine is reciprocating 6000 times a minute, with a fly-wheel turning round and dipping the irregularly-shaped big end of its crank into the so-called oil sump 55 times a second, it cannot reasonably be thought that the oil will all remain steady and level in its distribution.

CRANKCASE AND OIL "DUST"

By means of a glass-sided crankcase with a beam of light directed upon it, it is very easy to show that there is not much oil remaining in the bottom of the crankcase

whilst the engine is doing over 800 or 900 R.P.M. Most of the oil fills the crankcase with partially atomised or "dusted" oil, some of which takes up and dissolves out the petrol; which in turn will thin the oil if the fuel is paraffin or tar oil in character. Most of the oil is simply "dusted" into the crankcase and a skin is directed off by the fly-wheels and thrown off by scrapers on to the piston and gudgeon pin, incidentally putting extra load on to the fly-wheel and reducing mechanical efficiency.

This oil smoke or spray is exactly similar to that thrown out of most carburetter jets; one is light and partially vaporizes without delay, whilst the other, unless mechanically heated or else destroyed, remains as "dust" or spray. This oil "dust" can very well be used to assist or carry out the lubrication completely, because on account of surface leakage it is bound in any case to pass up the main crankshaft bearings.

It will be reasonable to point out, and it is a point in favour of mixture lubrication to realise, that it is useless picturing oil separating gradually round the piston at high

surface speeds. Oil put on one side remains there relatively to the speed of the piston, particularly in the centre percentages of the stroke. To obtain spreading without mechanical means is next to impossible, unless a large excess is available and the whole cylinder and piston surrounded by oil particles.

It is an advantage to pay attention to this fact and to assist lubrication by allowing the piston to leave the cylinder bore during its stroke and to provide oil rings upon it.

Petroil lubrication is by no means a novelty. Its rapid adoption on the two-stroke engine in particular is on account of the capability of the crankcase to act as a filter separator or fractional distiller, rather than on account of the extra heat necessitating a higher or more local degree of air pressure. The use of an oil spray from crankcase to inlet pipe is not at all new, and was in use long before petroil lubrication became a speciality, though the conditions are naturally different. For with the inlet pipe feed we have the oil being atomised partially and thrown into

the cylinder. While in the case of petroil, the combined mixture of heavy oil dissolved in thin fuel is spread simultaneously from the jet, which may not necessarily be warmed or mechanically stirred.

The results do not differ very greatly and might be adopted together with some success, because (particularly in the case of twin engines) it is very common to be troubled by badly lubricated pistons and sooted "back" cylinders, due to the driver endeavouring to find enough oil to replace that thrown off by the front cylinder or that furthest in the direction of motion from the top of the fly-wheel or crank discs. All these devices are of particular value in the case of steel or aluminium compound piston skirts.

A similar device has been used in the case of four-stroke engines by taking a lead from the crankcase to the carburetter jet. This should not, however, be applied to the exhaust except in the event of more vaporization being required. In this case any improvement noticeable is largely that of improved piston lubrication, rather than that of a pressure increase in the inlet pipe, which is

seldom closed to the atmosphere except in fairly high pressure feed two-strokes.

Even when the exhaust is fairly well scavenged or removed by crankcase or pump cylinders or combination of the two, it is really more important to obtain better inlet charging. This can only be got by raising the pressure considerably above that of the residual exhaust.

Piston lubrication is a very important point, most two-stroke engines using the piston as a sleeve or valve. Rotary piston valve or sleeve valve engines, however, use the piston as the complete valve itself, and in this case owing to the closeness of fit desirable, particularly on the opposite side to which pressure is obtained, on account of off-setting or the angularity of the connecting rod, when piston friction is removed there is not, as a rule, as much as 20 per cent. left of the total mechanical loss.

With a good stroke engine a very excellent mechanical efficiency can be obtained up to 90 per cent. and 95 per cent., but on many other engines under ordinary poor conditions 80 per cent. is not reached.

PETROIL EXPERIMENTS

It is a very interesting point that a mixture of petrol spirit and heavy oil can be used to run and lubricate an engine. It can be applied perfectly well on four-strokes, but the crank-case would need separate attention, as will be seen from the instances given before. This principle has at present therefore chiefly come to the front in connection with the small air-cooled two-stroke.

With mixture-lubricated engines the conditions are not similar to those in operation when an engine is being operated on heavy fuel oil, because in the latter case the lubricant—apart from the heat unburnt, unvaporized and dissociated particles—the fuel is entirely consumed.

When the temperatures are sufficiently high in the ordinary type of engine, this is just what we have to avoid by cooling and by oil in mass and under pressure at every bearing, but if the two oils pass *together* through the jet of the carburetter, partial vaporization of *both* takes place. The petrol vaporizes more rapidly than the oil, how-

ever well the latter may be dissolved in it, but even then not by any means instantaneously.

This particular fact is demonstrated with great ease by means of an engine with an inlet pipe and crankcase window of hard glass on both sides. Both crankcase and pipe compartment are illuminated by a powerful beam of light, and at 800 revolutions per minute the so-called gas can be examined at both points through a spectroscopic microscope. The result is a very beautiful experiment, for at frequent intervals and every time there is a slight shock in the gaseous mixture the different colours of the two oils in very fine particles can be clearly seen.

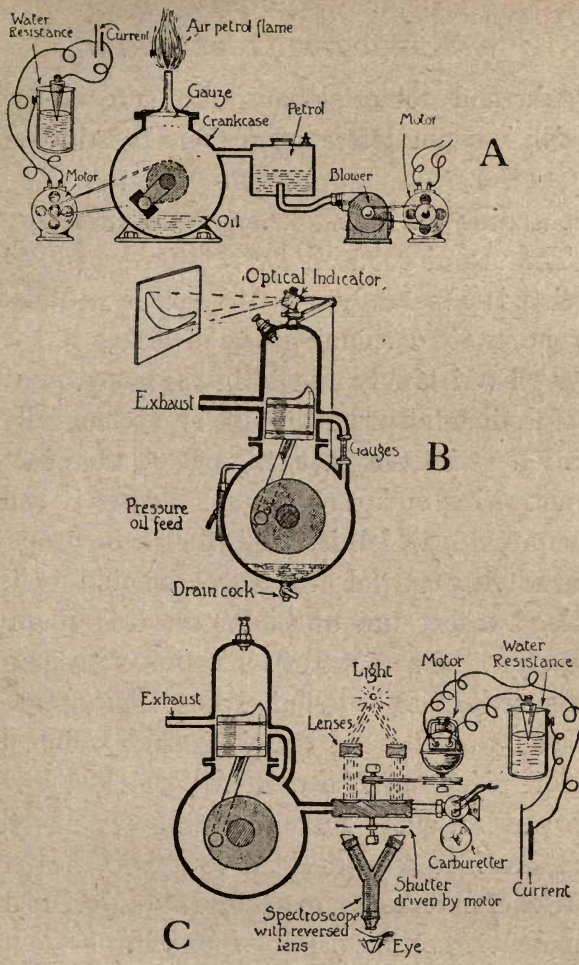
One never finds a great deal of oil in the inlet pipe, although it may be driven out unburnt and containing some fuel from the exhaust in large quantities. With a pipe from the carburetter up to 14 in. in length, with various arrangements for damping oscillations such as spring coils, as used in indicator work, very little oil condenses, proving that long after leaving the jet the petrol, as well as the oil, is only in the form

of dust and not of vapour; in spite of the rapidly varying temperatures and pressures.

MIXING OF FUEL AND LUBRICANT AFTER PARTIAL CARBURATION

With the same apparatus which is illustrated in the accompanying diagram, it has been clearly proved that if oil is sucked in at a jet leading into the inlet pipe or mechanically sprayed separately from the petrol, the effect is not the same, as it is not "dusted" and most of it will enter the cylinder in drops. The whole point of the petrol-oil mixture is that it enters the working parts as an impalpable "dust" and penetrates with persistency to every rubbing surface. The crankcase of this particular engine was examined under the beam of light, and the fuel and lubricant found to be thoroughly well mixed.

Both enter the crankcase from the inlet pipe and begin at once to vaporize from their small particles, all of which may be observed by the changes of colour. Unless the plant is so cold that the glass window indicates partial condensation through the spectroscope, the



LUBRICATION—DIAGRAM 1.

A. The existence of oil-smoke is easily proved by blowing carburetted air through a crankcase containing agitated oil.

B. The alteration in power by the varying oil-dust feed can be actually seen with an indicator. Gauges in the inlet pipe do not appreciably affect this.

C. It is possible actually to watch the gas travelling in the inlet pipe by a simple cinematograph apparatus also in the head.

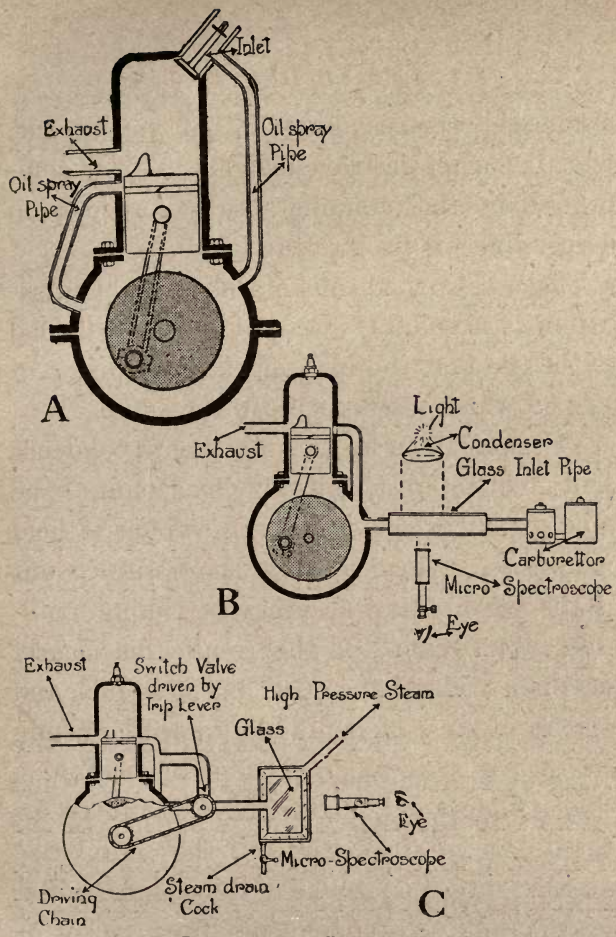
crankcase becomes almost full of true vapour, which is again destroyed slightly as it is compressed by the pumping action of the piston descending on its stroke.

The use of good oil for this form of lubrication is absolutely necessary or it will lead to the gradual thinning of the oil film or of any oil which may remain in the sump.

The time taken for this mixture to condense is of great interest, not only on account of the time during which the petrol vapour is held compressed, which is quite short on account of the very partial accuracy of timing available, but because of the result this clearly has upon the amount of oil burnt as fuel, and because it must be definitely known how long the oil particles will remain in suspension.

The Diagram 2 shows how this may be tested by short-circuiting the crankcase mixture into a glass-sided container, heated to the crankcase temperature by a jacket of superheated steam passing round it.

It was found that when the petrol was permitted to condense, the oil took an appreciable time to follow suit. This is of interest and value, for the conditions were those of an



LUBRICATION—DIAGRAM 2.

A. An oil-spray to the cylinder is frequently valuable for both two- and four-stroke engines.

B. The two oils can be examined in the inlet pipe, and it will be found that they are unvaporized.

C. A charge of mixture was examined, and both fuel and oil condensed in turn.

ordinary working engine; and varying condensation due to the pump side of the piston was avoided by only allowing one charge to interrupt the engine for each test of one stroke.

This experiment cannot be conveniently conducted at speeds over 300 R.P.M. The oil in the mixture only vaporizes to a slight extent, solid particles being always noticeable, although the petrol may be largely gasefied. When running on full load an appreciable time elapses before condensation allows suspended oil particles to recoagulate into visible oil.

The temperatures during this experiment do not vary very largely on the inlet side unless large power or Diesel engines are being operated upon. Part of the oil which passes into the engine always collects in the crankcase, which, however, can be left open if necessary, just as the bearing of an ordinary two-stroke engine can sometimes be reamered out without preventing its working. If oil dust can lubricate an engine successfully, it is proof of the fact that most oil throwers and most crankcase oil layers which are

expected to be correctly dipped in at a speed of perhaps 2000 R.P.M. are not of great value.

Round each pressure surface the oil coagulates as it does whilst being used in every bearing, part of the oil remains in suspension and is driven or forced in the cylinder, where it undergoes somewhat the same process, lubricating the piston rings and gudgeon pin with a thoroughness easily obtainable in this fine state of division, and considerably assisting the possibility of a good fitting piston skirt, which is valuable.

Being under the slight pressure of partial vaporization it is assisted in its work, but not sufficiently to be of real value at the bearings, and for best efficiency there should be a pressure supply at this point and to the piston.

Both petroil and pump should be mechanically operated and gauged, and should be also under the sight and control of the operator. Much of the oil condensing on the piston is in true liquid form, enabling some benefit to be obtained from the oil which is only partially spread, for it will not evaporate or burn

off the relatively cool walls during the power or exhaust period.

As far as the maximum power is concerned, a combination of pressure and mixture lubrication is far better than the use of petroil alone; though on the score of simplicity there are few engines so fitted even with combined oil sprayers and pumps.

Nearly every two-stroke engine with crank compression is lubricated partly by the "petroil" or "smoke-oil," because the oil is always in a state of high speed agitation; and, especially when the crankcase is warm, a considerable quantity of oil is carried over into the working cylinder. In a two-stroke engine with a pump cylinder, in some scavenging, and in other four-stroke engines, the same thing is taking place to some extent—which leads us to a very interesting branch of the subject.

When the oil-smoke is raised to a fairly high temperature in the charging side, some of the oil is vaporized. In any case, when the finely-divided oil reaches the working cylinder, after the work done on it by part expansion and after it has lubricated other parts, the

temperature of the power cylinder is high, and quite a large proportion of the oil will be evaporated before and during the explosion. It thereby upsets or enriches the mixture with a heavier oil so that considerably more oil than that really required for lubrication may be used to obtain high mechanical efficiency from the engine.

In large engines this would be a serious matter, causing a very high oil consumption and the formation of carbon in a free state, so that a mechanical sprayer would become necessary in place of the separating effect of the lighter spirit. When benzole is used, the freeing of unburnt carbon becomes still easier. Particularly in the case of two-stroke engines running on the petrol-oil mixture, the lubrication is very noticeably affected by the nature of the fuel and oil, quite apart from their lubricating properties, but this is no very great disadvantage in small cyclecar engines, except with paraffin fuels, which are liable to thin out the lubricant.

The effect of semi- and totally vaporized lubricant is not without its benefit on carburation and general running. Many years

ago a form of carburetter existed in which the inlet suction raised an air disc and with it a needle valve, thus controlling the supply of fuel and also of the oil by the simple expedient of connecting the vaporizer to the oil tank or crankcase. If the latter is used as a pump or additional air scavenge, coupled with a double-acting slide on the connecting rod, it is possible to combine the oil and petrol sprayers.

Most of the heavier oils are rich in carbon, and consequently the " oil-smoke " lubrication of an engine will frequently not only raise the mechanical efficiency, but also increase the mean effective pressure. With most small two-stroke engines this experiment can be conducted in quite a simple manner, and by using a specially designed optical indicator, the " card " shape can be seen to alter as the oil is turned on and off to the engine feed. A two per cent. increase in horse-power has been obtained more than once, although very accurate measurements are difficult and require a great amount of patience.

Taken all round, the two-stroke engine, such as the Levis or Triumph, is exceedingly

satisfactory. The former demonstrated, with the winning Scott, what could be done during the 1914 Tourist Trophy race in the way of pulling at slow speeds. This is one of the very qualities, in conjunction with balance and smooth torque, which is of such value to cyclecars—far above that of fuel economy.

This all goes to show that a little "oil-smoke" is an excellent thing, for it is practically universal on this type of engine as soon as the speed reaches more than 600 R.P.M. This has been proved by examination by spectroscope and by other more simple means.

The cylinder was removed from the test engine and a short pipe substituted, in which were placed a few gauzes. These have little effect and increase general safety. The engine was then run by a belt at 2000 R.P.M. with a dummy big end in place and a stream of carburetted air passed through the crankcase and up the pipe. When the engine is emptied of oil, the flame is that of air-petrol, and when it has only a little lubricant in it, the flame can be seen to be that of air-petrol-heavy-oil quite clearly with the naked eye.

This proves what conditions are in force

during running for the first time, and can be confirmed by an ordinary quartz window in the combustion head.

As has been mentioned before, oil-dust lubrication is excellent in many ways, but with an engine running at such widely different temperatures as obtain on a small car, a large increase of load will usually increase the cylinder temperature to an abnormal degree. Much oil will be burnt, the lubrication value of the mixture being consequently decreased. This might be serious in racing, and is certainly another argument for a variable oil feed or a mechanical oil "duster," especially in larger-sized engines, in which a rather excessive amount of oil has to be mixed with the fuel proper.

More especially in the case of engines where the mixture is enriched on its way to the cylinder, or where a strong mixture is diluted by some additional air, there exists a condition of two vapours and air which is liable to flood the cylinder at the expense of the crankcase, where most separation occurs under the usual temperatures and pressures. A high compression in the crankcase shows on experiment

remarkably rapid oil separation. A high pressure therefore is frequently necessary so that the inlet gas may whirl sufficiently without the suction turbulence causing wastage, but enough to ensure ignition at low speeds and rapid total combustion at high speeds. This is as important from a lubrication point of view as is scavenging, for if a fresh mixture of "petroil" is not assured, pre-ignition may raise the engine temperature to a point where most of the lubricant is consumed.

In engines with a pump piston and high inlet pressure this is so marked that one can graduate lubrication by varying the pressure of the gas consequent upon its speed of flow through the ports and inlet pipes. Another point observed by actual practical tests and by a reduction of port area is that oil can be sprayed as dust on to gudgeon pins, though this is difficult to secure except on the test bench. There can be little doubt that the right thing to do is to lubricate any bearing by oil under pressure : but in no case can this be so extensively carried out as to ensure the oil reaching all parts, as is the case with "petroil."

In small engines this is of no consequence, but in large-size — and especially in high-pressure—engines the cylinder volume is large relative to the cooling surface, causing much oil to be burnt and making additional pressure essential for proper oiling of the piston. If this is not done, nearly 15 per cent. more oil must be mixed with the fuel, and carbon will quickly collect on both plugs and valve ports.

LUBRICATION THAT COOLS THE ENGINE

With four-stroke engines also, a combination of spray and pressure oiling is good, for it does away with the absurdity of ten miles smoking and ten miles under lubrication, due to the use of pumps. The addition of steam or water to the crankcase will help to keep an engine cool, with the oil in suspension, and by means of the apparatus already described the colours of steam-petrol-oil particles can be noticed, though, strictly speaking, the water should be injected on to the metal walls of the combustion space and not into the gas.

With the four-stroke engine, however, the crankcase cannot usually act as a separator. Neither can it separate out oil into dust so

conveniently from the fuel. For the inlet gases are not so hot, and the lubricant may separate out and not all be consumed when it is fired by the petrol, thus leading to inevitable plug sooting, use of much oil, and calling for separate regulation under different loads.

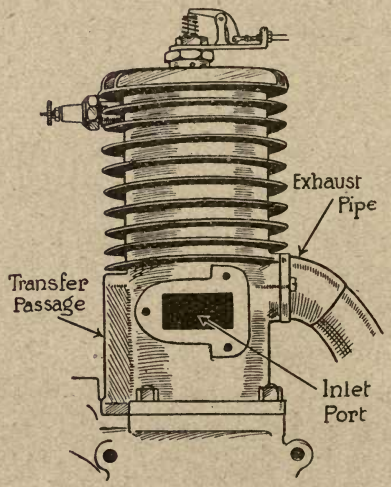
The remedy is to lubricate by the pressure pump and spray, varying the quantity when required by interconnecting the pump sprayer and throttle. Almost any four- or two-stroke pump type is improved by the addition of an oil pipe from the crankcase to the inlet. And, better still, the oil scavenge pipe to the cylinder, although the latter has seldom been used, so that the conclusions from all these experiments are fairly obvious.

To recapitulate, it may be pointed out how wrong it is to think of four- and two-stroke engines as being so very different, both being badly oiled to an equal degree if fed by irregular splashes. They require more accurate treatment than is obtained by the chance passage of " dusted " oil from the crankcase to the piston skirt, according to the work to be done.

Any engine will benefit by forced lubrica-

tion and beyond the wastefulness of "dusted" oil not much can be said against it. This disadvantage is avoidable by a control on the sprayer.

Lubrication is not merely a question of keeping a bearing cool, and a large increase in



TYPES OF TWO-STROKE ENGINES.

Cylinder of the Radco with transfer passage cast in the base.

B.H.P. may often be obtained by the re-design of an oil system. These indicator experiments have shown the two chief causes at work quite apart from the question of

crankcase carburation and a $1\frac{1}{2}$ per cent. improvement is usually available from any small engine.

CINEMATOGRAPHIC OBSERVATIONS OF PETROIL

One of the most interesting and beautiful experiments that can be conducted on the subject of petroil lubrication is that of the examination of the mixture at different points of the inlet pipe. This can be done by the same method as is adopted for the examination of exhaust valve bouncing, because the passage of gas along an inlet pipe is on examination only a question of relative speed. To examine the same portion—or globules—of gas at different points in the glass inlet pipe, narrow beams of light are projected as shown in the diagram (No. 1, C), through sections of inlet pipe—about four inches apart to eliminate pipe friction. A cinematographic disc is arranged with two slots to be revolved, synchronously with the engine at different speeds, by a small motor in series with a water resistance.

The disc uncovers alternately each different section in the pipe, which is examined by the

same eye through a spectroscope with the eye-piece and prism lens reversed.

The gas and oil colour varies all the time as the mixture vaporizes whilst passing up the pipe, so that it is possible actually to study the petrol liquid and oil during evaporation at speed. This has proved very clearly that the petrol carries the oil in almost complete suspension without vaporizing. This is a point in favour of petroil lubrication, and also shows how the crankcase of a two-stroke engine helps to convert the finely divided petrol from the carburetter into a partial vapour. The speed of the gas and shutter are synchronised as accurately as possible before each observation, when whirling of the mixture in the pipe becomes a minimum.

TUNING DETAILS

It has very often been considered that a two-stroke is much more costly and complicated to run than the ordinary four-stroke motor. This has probably arisen from the use of complicated pump engines and large Diesel plants of the two-stroke variety. At the present time, however, the two-stroke motorcycle engine particularly is usually considered one of the simplest forms of prime mover known, and also one of the cheapest to use in the long run.

There are not many peculiarities possessed by two-stroke engines, and all of them have become evident after a little study of actual working facts—as apart from really secondary considerations of design—so that if the points of one or two makes or types are given there will be no difficulty in sorting out the idiosyncrasies of different engines and maintaining them in good and economical condition.

TUNING SCOTT ENGINES

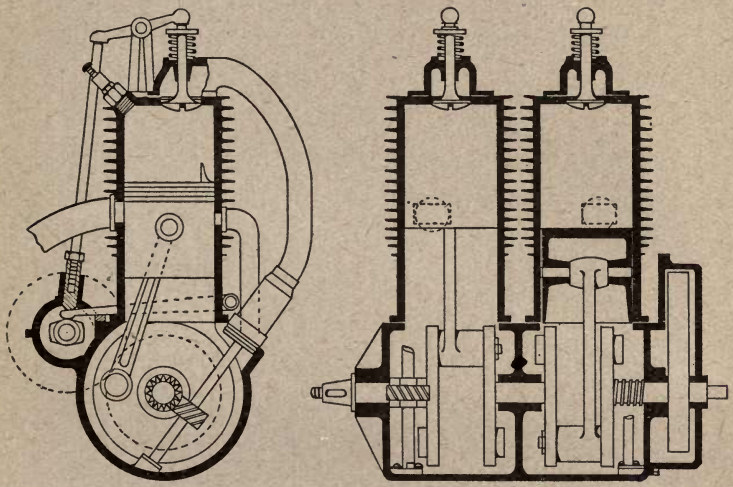
The Scott engine is exceedingly simple, as is evident from the details already given, but being twin cylinder sometimes has the appearance of complication.

The Scott engine illustrated (p. 22) should be referred to by the reader. On any small two-stroke the prevention of air leaks and the avoidance of over lubrication and consequent piston-ring troubles are very important, although with large single two-strokes it has been possible to run them with quite free access of air to the crankcase through bad bearings or open drain cocks, owing to their low pumping compression.

Low crankcase compression, however, is not to be sought for except when arranging for smoothness and avoidance of shock on the inlet side, leading as it does to shock condensation as apart from total or local temperature condensation, much of which is avoidable by the ordinary considerations of carburation.

On the Scott engine loss of crankcase compression may take place at the cylinder base,

the crankcase doors, or the transfer port covers. Very little leakage can take place at bearings unless the packing glands are actually spoilt by under lubrication. When examining the engine after the cylinder has been removed for cleaning, the cylinder base leakage should receive attention and new rubber rings put in, together with a new linen ring where the joint occurs.



TYPES OF TWO-STROKE ENGINES: CROSS SECTIONS OF THE EVERY-CLAYTON.

Mixture is drawn into the crankcase through a rotary distributer valve, and some is also transferred in the ordinary manner. The charge then passes into the cylinder through a mechanical inlet valve in the head. The inlet dwell is, of course, long and effective, though the engine becomes rather complicated. This engine has shew gear drives for the rotary valves. The inlet valves are mechanically operated.

Needless to say care should be used to see that the rings are put in evenly and the bolts regularly tightened down at opposite corners, using the spanner a little at the time upon each nut. In replacing the crankcase bearings great care must be taken to clean the washers, for not only will this cause leakage but also internal damage, and the door should always be let down on a clean place when replacing the acreite.

The transfer port covers are possibly the most common seat of leakage, and the gauzes which are pressed together by a lead washer should be smeared, where the lead washer shows, with any sticky gum, and then the acreite washers placed upon them until dry. This fastens the two sets of washers together, and when the port and transfer faces have been cleaned with petrol, the gauzes and acreite washers should then be gummed, put in position whilst tacky, and the cover evenly and firmly bolted down. It is advisable to leave these joints to harden for a night before running the engine, though slight leakage of oil from the engine need not be feared.

When these points have been attended to the crankcase compression should be perfect, the plugs should be removed for a test, the low gearing engaged and the back wheel pulled sharply over whilst listening round the engine and smearing the joints with oil. As the gas in the crankcase is released by the piston uncovering the ports the sound should be quite sharp and clear. The sparking plug should be kept clean, those of the Reliance type being very suitable, and they should also be tested for leakage.

To maintain tune in every way and also economy it is important to keep exhaust ports and silencers clean; the exhaust ports can easily be cleaned by removing the screws holding on cover plates and then scraping away carbon.

Much of the carbon deposit on the piston also can be removed through these plates. The large silencer will not require frequent attention, but the auxiliary silencer requires looking at quite frequently, as it is most important that it should be kept quite clear.

As far as carburation is concerned the car-

buretter needs little attention, but the air valve should be examined to see that it does not stick open and thus cause difficulty in starting and slow running. The dash pot should not be filled with oil.

Needless to say the water radiators require occasional cleaning both inside and out, and a point worthy of note is that with the Scott machine and carburetter benzole can be very easily used, having in fact one or two slight advantages especially when used with petrol.

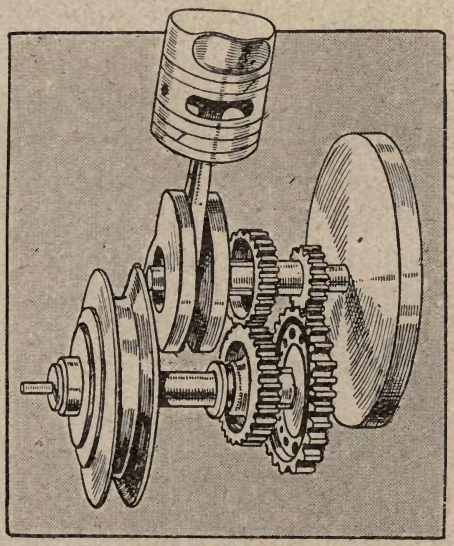
CLYNO MOTORS

The Clyno engine is one of the simplest single-cylinder types ; but a tenth part of the attention given to it compared with that required on a poppet spring or non-force-controlled valve engine, is always well repaid.

Even on an engine which has a small diameter piston it is important that it should be a good fit and well lubricated, acting as it does in place of the ordinary valves ; it is, however, important to see that the rings are always free in their grooves, and this applies to every two-stroke. It can be safely said

that notes on tuning any motor apply almost in detail to all other machines.

The detachable transfer port on the Clyno is convenient for examining piston rings, and



Clyno Two-Stroke, showing two-speed gear and clutch.

this joint must be very carefully re-made after breakage. The crankcase joints should be kept pressure-tight to avoid compression or charge admixture loss after any lubrication examinations, etc. The best method of making

this joint is to use a thin paper washer coated on both sides with gold size and allowed to get thoroughly tacky for replacement.

On the small Clyno engines there is only one ring used to prevent loss through the bearings, but this is not a very frequent source of trouble and it can be replaced or renewed both as regards packing and main wearing surfaces.

The cylinder should be carefully cleaned of carbon deposit, together with the ports, and with petroil lubrication (unless it is employed mechanically and in conjunction with pressure lubrication, which is better still); it is important to look very carefully after carbon deposit on the ports and combustion head. The same applies to the silencer arrangements, which must be carefully kept clean, and beyond these details there is little else to do beyond the ordinary cleaning of carburetter and magneto.

As with most two-stroke engines a plug with rather heavy electrodes is advisable, although the mass of high tension insulated metal should not be so great as to cause condensation, and a hollow-pointed plug is rather advantageous on many motors of this type.

Details of this engine have been already illustrated very clearly.

THE LEVIS ENGINE

The Levis engine has also been illustrated and requires no particular attention other than the ordinary details, but some notes on cleaning the engine about every two thousand miles if the lubrication is properly attended to will apply to other motors as well.

When the engine has been removed from the frame and thoroughly cleaned with petrol and paraffin the oil ways should be cleared in crankshaft, crankcase and gudgeon pin.

The cylinder head piston top and ports must be all thoroughly cleaned and the rings examined for freedom from side play and easiness of fit. The compression valve should be ground in the ordinary way, and particular care taken that the spring retainer is thoroughly strong.

Joints should be made of gold size and paper as already described; the gudgeon pin is removed by driving out towards the oil-feeding side and the cylinder base washer cut from thick even brown paper, gold sized as

usual. The magneto requires two or three drops of oil every five hundred miles, and the high tension brush and contact breaker brush should be cleaned and the platinum points adjusted and set to the usual width of about ·4 mm. The rocker arm should not be oiled but should be touched round lightly with vaseline, and when replacing the whole magneto the engine sprockets should be lined up carefully before finally bolting down.

When removing the fly-wheel care should be taken not to damage the adapter, which should be well cleaned before replacement, and when it has been tapped gently into position the nut should be tightened very firmly by locking the spanner up and then hammering on the spanner with a mallet until all is thoroughly tight. The same tightening process also applies to the sprocket wheel for the magneto. To time the engine place the piston on top centre by looking through the carburetter port before putting back the carburetter, and set the contact breaker halfway across with the points almost fully retarded. This adjustment is made by adjusting the sprocket wheel on the crankshaft end and

not on the magneto itself. The petrol level may be usually lower on two-stroke engines owing to the high velocity vacuum suck available, and may be set about one-sixteenth of an inch below the jet, when full air should be available at high speeds.

The carburetter lug should be also treated with several coatings of gold size before replacement. A thin grade oil should be used and a long reach sparking plug fitted.

CONNAUGHT TWO-STROKE MOTOR

The Connaught engine is interesting on account of the means adopted and illustrated (on p. 29) for keeping the inlet gas warm, thus doing away with local condensation, etc. It is of the three port type, that is to say has transfer, carburetter and piston ports, and does not rely on the two ports only.

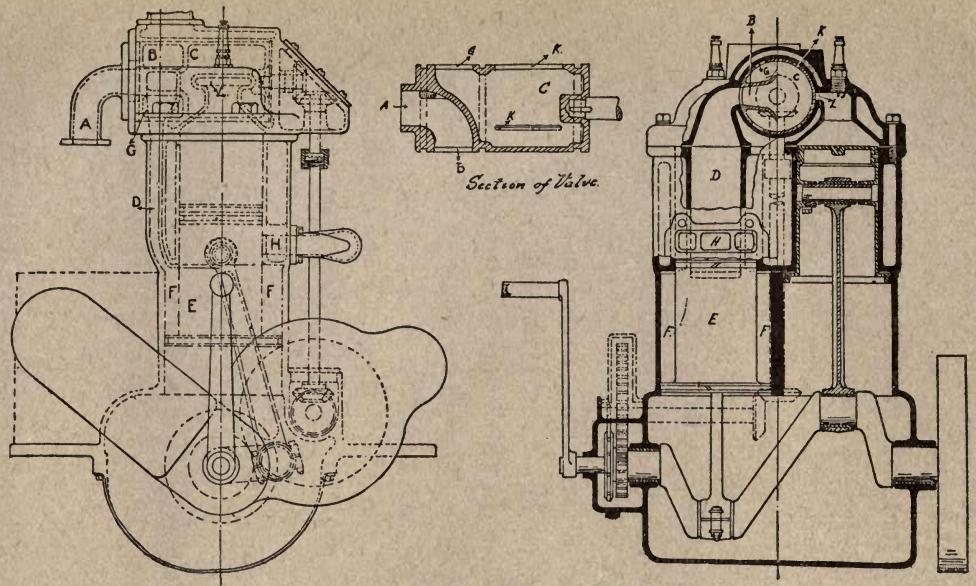
One of the most important points is to remove the carbon deposit off the exhaust ports after every six hundred miles and also thoroughly clean all the edges. Carbon also should be removed from the top piston ring both in this and in all other engines, in which deposit will usually accumulate. Very little

carbon collects on the piston chamber of a Connaught, but if any is there it should be scraped carefully away and the piston top carefully polished over with graphite.

For ordinary running use a 30 jet in the Senspray carburetter, but a 32 may be used for sidecar work and the petrol level raised about one-sixteenth inch by filing a groove in the needle one-eighth higher than that already in it.

A small air tap is useful in the induction pipe between carburetter and inlet port to crankcase, as this allows air to be admitted. This engine will take a considerable amount of extra air, especially if a funnel is affixed in the direction of travel to the carburetter. Sparking plugs of good usual types are satisfactory, but the points should not project appreciably beyond the body. To time the engine remove the magneto chain and slacken the crankshaft sprocket. By placing the finger in the sparking plug hole bring the piston to the top of its stroke, revolving the fly-wheel carefully.

Then turn contact breaker until the points have just broken with spark lever fully re-



TYPES OF TWO-STROKE ENGINES: SECTIONAL ELEVATION OF THE PATCHETT AND BOOTH.

A. Induction pipe. B. Induction port. C. Rotary valve. D. Transfer passage. E. Piston.
F. Pump cylinder. G. Transfer port in valve. H. Exhaust port. K. Inlet or distributing port in valve.
L. Inlet port in cylinder.

This engine is simply a differential piston engine with rotary valve control.
It is rather more complicated than most engines, but satisfactory.

tarded and without moving anything; thoroughly tighten up the crankshaft sprocket and replace the cover. For fast work the contact breaker wipe may be set a quarter in advance of its cam with the piston at the top of its stroke. Good thin oil should be used as usual, and if the engine is frequently decarbonized it will be found advisable to use plenty of lubricant.

There is scarcely any need to go into details of any other two-strokes as regards tuning, because the details really depend entirely upon the actual construction and the principles will be quite clear in the reader's mind.

GENERAL TWO-STROKE NOTES

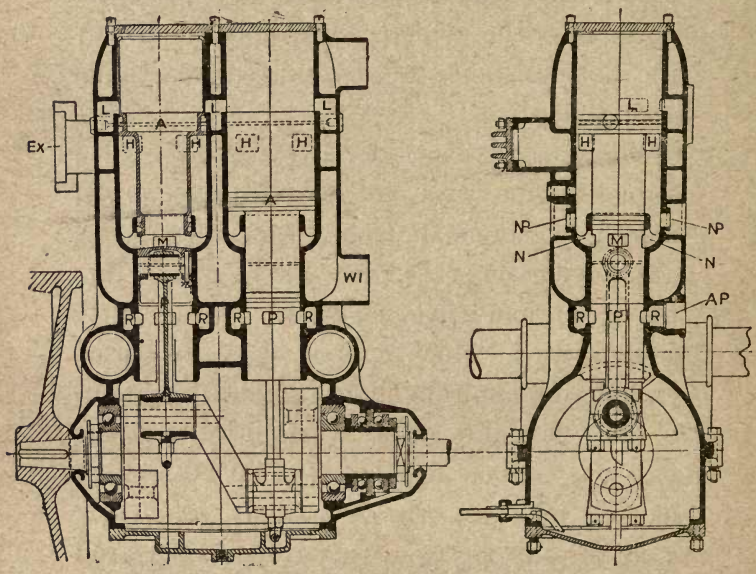
Valve-Port Timing

The question of shape and area of valve ports has already been gone into ; they should, broadly speaking, be as large as possible. One of the great troubles with the two-stroke is that having only 15 lbs. per sq. in. atmosphere to fill the crankcase, and then having the loss of pump efficiency which is present in any engine, it is not possible to get all the gas into the cylinder when wanted, and owing to the high vacuum created in the majority of these engines it is very difficult to avoid inlet shock by equalizing the areas of pipe conductors, ports, and containers.

The whole question lies in the fact that however hot the gas may be to prevent crankcase deposition during whirling, which is often stopped by the addition of pump apparatus, inlet shock due to the rapid suction will cause loss of petrol, bad mixture and choking of the engine in the inlet pipe side.

In the case of engines with pump systems, it is quite easy by careful design to obtain a smooth and regular supply of gas, allowing

for all the many details of temperature variation. But in the crankcase compression engine, if we have a very large dwell for carburetter suction we will lose it by transferring to the combustion chamber, and we must remember that we are not varying our compression in most engines other than



TYPES OF TWO-STROKE ENGINES.

The Harding Engine is of the pump piston type, but has no valves or springs, although the space is scavenged right across. The resulting purity of explodable mixture is very satisfactory.

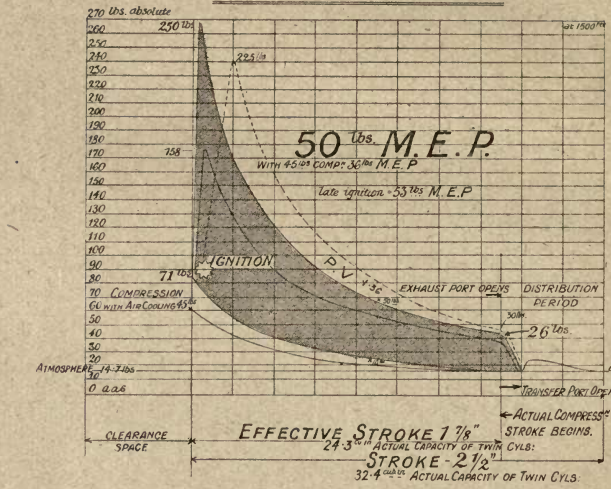
A. Trunk piston.
M. Transfer port in piston.
EX. Exhaust pipe.
L. Mixture inlet ports.
P. Connecting rod.
WI. Water inlet.
H. Exhaust ports.
R. Air inlet ports.
NP. Sparking plug orifices.

by cutting down the throttle opening, thus attenuating the charge and mixture.

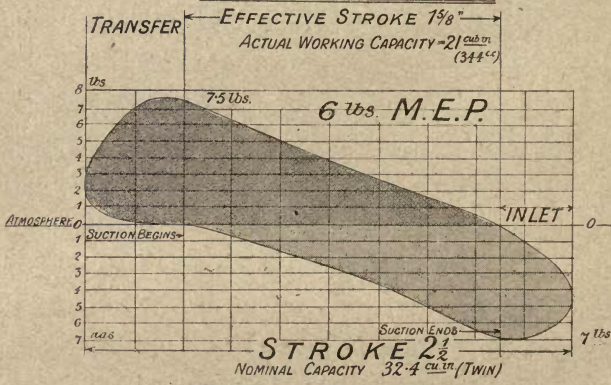
Once we can get atomization, which is often easier with a two-stroke than with other engines, it is very important to see that the passages and ports are arranged so that there are no rapid changes of volume, as the gas leaves each part of its conducting pipes and ports into the cylinder, where it is met by the hot resistance of residual or scavenging gases and air.

We do, however, do away on the two-stroke engine with valve and valve spring inertia questions in most cases, because we are relying on a definite piston speed. On the other hand, we have gaseous inertia to contend with, which cannot be easily varied except on multi-cylinder engines, and to obtain flexibility one must have suitable passages of issue for the gases on both sides, namely, inlet and exhaust, and also frequently a carburetter lag to cause local enriching and to provide a mixture explodable at ordinary speeds. The question of gaseous expansion in the cylinder must be carefully worked out

CYLINDER DIAGRAM.



CRANKCASE DIAGRAM



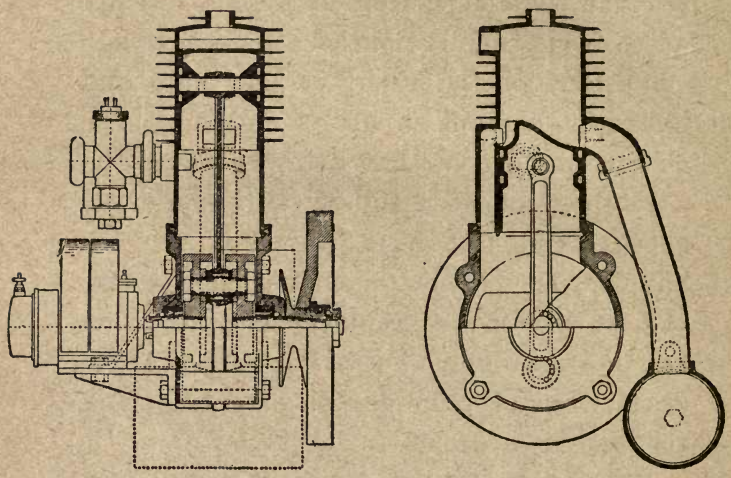
TYPICAL INDICATOR CARDS.

The actual cards taken by the Low oscillographic manograph are very distorted at high speeds. Taken from Scott Engine.

so that the temperature changes only take place on the power stroke, this being arranged by means of the timing, taking into consideration the amount of gas in motion and its position and pressure at every speed.

If the cylinder is full of gas and the explosion takes place with the piston just over the top centre we can show by means of an indicator, or oscillographic manograph, how the pressure gradually rises generally to about three times the compression pressure (which on most two-strokes is fairly low to avoid excessive exhaust pressure), and then the burning gases expand as the piston travels down the stroke after the fashion of the indicator diagram shown opposite.

In order to get rid of the exhaust gas promptly, and with crankcase or with " piston-operated " valves as distinguished from piston valves, it is necessary that the exhaust port should be uncovered considerably before the end of the stroke ; and then as there is only a short period for the inlet gas to get in, and as the longer the inlet port is kept open the more can be lost and subjected to shock on the compression stroke, the inlet port should



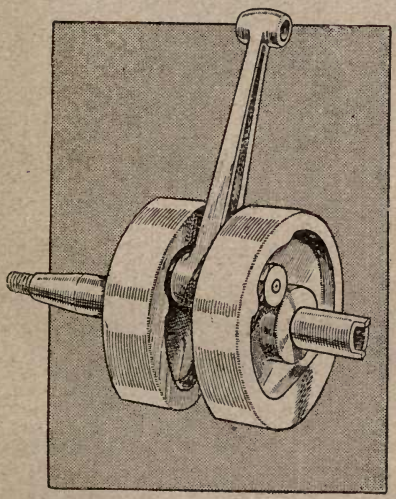
The T.D.C. Engine has its transfer inlet and exhaust ports cast in one piece, and has two fly-wheels within the crankcase and an additional fly-wheel outside. It is a good example of overall design.

be opened almost immediately after the exhaust or possibly six or eight degrees after, as shown in the diagram.

The exhaust and the inlet ports will both be closed shortly after passing the bottom centre, the inlet being closed first, and the piston then travels up compressing the gases. Clearly it is a point of the greatest importance to see, depending on what speeds and what choke area we have an engine running at, what are the size of the ports, so that the gases

are allowed *as much time as possible* to enter and leave the cylinder without undue eddying.

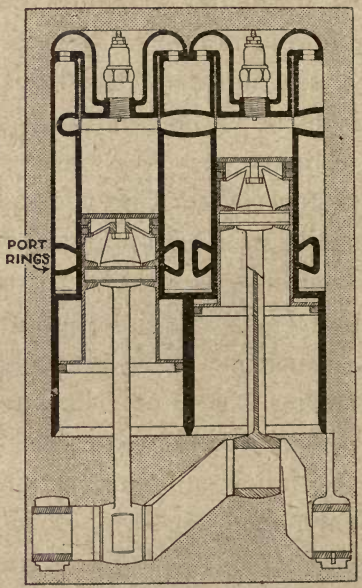
Condensation is a very serious point and is usually due to both lack of warming of the charge and internal shock in the gas. The gas cannot be warmed unduly because the effective weight of the charge will be reduced, and for this reason the inlet should always be kept open as long as possible, especially in a long-stroke engine, which is not easy to design without valve gear when operated on the two-stroke principle.



Two heavy inside fly-wheels of the T.D.C. Engine.

The exhaust on a two-stroke is usually opened rather too early—because there is no definite medium pushing out the burnt gases; and in order to avoid too great a loss it is often desirable to split the exhaust port

up and obtain a very free exit in as short an angle as possible turned through by the crank pin. In this we are slightly assisted by the natural dwell taking place when the piston is at the slower parts of its motion, and it might be advantageous to offset the cylinders of small two-strokes more than has been adopted as a general rule.



THE CROSSLEY TWO-STROKE PUMP CONCENTRIC PISTON ENGINE, RING PORTED. 25 H.P.

CARBURATION

Carburation for two-strokes even more than in the case of four-stroke engines is dependent very much on inlet timing and the inlet or pumping side of the engine. Details of carburation for particular machines have been given in a few instances to save the reader time, but a few notes on the principles involved will not be without interest.

In the ordinary way we have petrol or other liquid fuel passing into a carburetter which is usually in a high state of vibration, and this carburetter is allowed to send a jet of liquid petrol into an inlet pipe through which air, sometimes cold and sometimes warm, is rushing exceedingly fast and eddying round every odd corner in its vain endeavour to follow up the piston, having behind it only about 15 lbs. per sq. inch of the atmosphere.

It is very much the same as upsetting a little petrol in one corner of a room and then striking a match the other side and expecting

an even mixture of petrol gas and air to explode without loss. Needless to say, what actually happens is that the carburetter does not really "carburett" at all, and with a four-stroke engine, where the periods and moments of suction could be carefully regulated, this is not quite so serious as with two-stroke engines, where there is a sudden suck, during which it is vitally important to obtain a gaseous mixture which must not take long owing to the small amount of valve dwell which is usually available.

In order that there may be a certain amount of rich mixture to flow over the sparking plug it usually pays to adjust one's level lower than with a four-stroke, and to allow a certain amount of lag in the petrol column, thus giving a rich section of mixture just before the inlet port is closed by the ascending piston.

As has been demonstrated in the section of petroil lubrication, the petroil after leaving the jet spreads into a number of small particles, and when oil is used with the petrol vaporization is slightly impeded, the oil being suspended in the particles of petrol and not

deposited in the pipe, as it would be if the petrol were gasified.

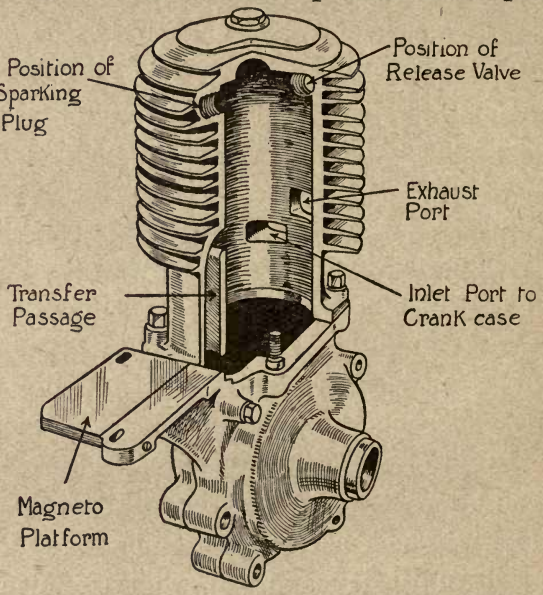
The petrol and entering air should really both be slightly warmed, but even then the engine fires a mixture of air and petrol particles together with a small amount of vaporized petrol, which is not recondensed by compression owing to the heat put into it to supply the latent heat of vaporization taken from the rarefied gas in the inlet ports during suction.

Quite a lot of petrol is often wasted by mixing with the lubricant in the crankcase unintentionally, and quite a lot is wasted via the exhaust. Good vaporization and a well-warmed petrol supply are essential on two-stroke engines, and more attention should be given to " wick," " yawning " and pressure carburetters, operating either to break up the petrol as much as possible, or better still to heat it until it vaporizes, as is frequently done in forced induction and oil engines.

This principle is likely to come into being for two-stroke and even petrol-turbine practice, and in conjunction with water injection

or steam jets to metallic parts or the gas itself it may yet solve a few of the problems of the internal combustion engine.

It is naturally important for efficiency that the speed of combustion should be high, because the faster the explosion takes place



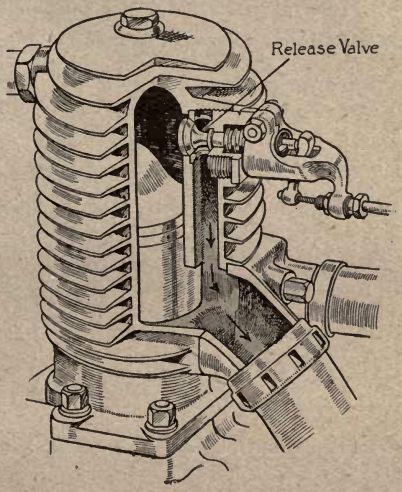
SECTION OF TRIUMPH TWO-STROKE ENGINE, SHOWING DISPOSITION OF THE VARIOUS PARTS.

the greater will be the thermal efficiency of the explosion or burning. On the other hand, it is desirable to be able to operate on a slow-burning mixture to obtain power at low

speeds and thus effectively avoid transmission losses.

This is a point in which the two-stroke really excels when operating at its highest load. With most carburetters it is practically impossible to vary the amount of petrol admitted per stroke, but much can be done by preventing mixture variation by means of jet damping, and incidentally by damping of the needle valve which usually controls the petrol level.

Carburation and inlet design go together; the problem is to avoid inlet shock and at



SECTION OF TRIUMPH CYLINDER WITH COMPRESSION RELEASE GASES LED INTO THE EXHAUST PIPE.

the same time to have a regular suction on the jet, because one is dealing with two rapidly moving columns, and the friction caused should be used not to damp the flow of gaseous air or the liquid column of petrol, but to mix one into the other by damping their internal friction.

Two-stroke engines have the name for wastefulness. With crankcase compression a slight amount of waste is usually felt unless some pressure-raising device is fitted, but most of the trouble can be avoided by supplying the crankcase with a gas and not with irregular spirts of petrol due to sudden suction on a jet containing petrol at varying levels and in various degrees of motion and of temperature.

The use of paraffin and benzole, either alone or together, so long as proper means are taken to warm the carburetter is often easier with a two-stroke engine than with any other, on account of the mixing period available in the crankcase, but, on the other hand, extra temperature is necessary at the carburetter to allow for the greater period during which the gas has to keep in suspension the liquid fuel.

In atmospheric inlet engines the gas should be vaporized, and in Diesel engines its liquid form often helps to obtain a reasonably slow explosion. But, on the other hand, if the principle of forced induction supply is to be applied to small engines, in order to obtain control, the fuel usually has to be vaporized either separately or by means of the engine's own heat.

Most two-stroke engines would benefit enormously by a sleeve giving variable timing and it would not greatly complicate the design. A slow explosion is no great disadvantage if flexibility of the engine is obtained, and the greatest care is necessary in the design of inlet pipes, which on a two-stroke engine is often helped by length and by the addition of a hot lead to the air supply. When the inlet port shuts, the gas travelling fast oscillates in the inlet pipe just as an exhaust gas does in an exhaust pipe, and this causes again more condensation, more increase in petrol consumption and more liability to misfiring.

One of the greatest helps a two-stroke could receive is that of supplying it with

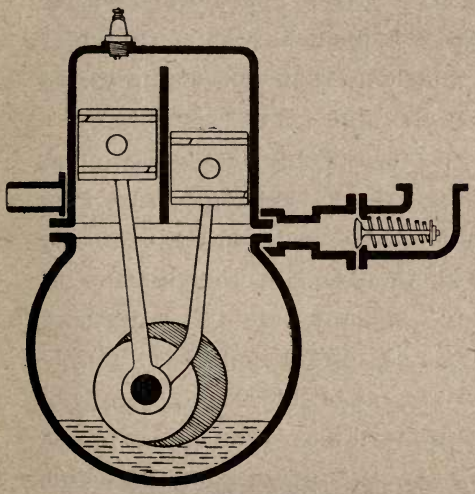
proper gas instead of varying its fuel supply only, and much more attention should be given to this point.

It is extremely difficult to secure lack of condensation due to the petrol continuing to rush through the jet when no more is required, because if it is arranged freely to help a quick supply of gas it is sure to give local flooding when the throttle is opened.

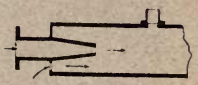
When we consider that the compression stroke possibly occupies the twentieth of a second it is easy to see that unless real gas is in the cylinder the increase of pressure may more than make up for the rise in temperature. There is very little time for the mixture to form because of the short period of induction, and one can usually obtain more satisfactory results by having a fairly long column of petrol and air in motion at right angles to the final direction of engine suction, and this might well lead to the adoption of a carburetter having a variable jet angle, in conjunction with a wick, because the jet exit friction could then be varied and the amount of damping varied for different speeds. Naturally the more irregular the suction of

an engine the more difficult it is to obtain regularity of carburation, so that on single cylinder two-strokes very large carburetters have to be used and unfortunately few of them have proper warming or vaporizing devices.

Flexibility and effectiveness of explosion are



CENTRE-LINE SECTION.



EXHAUST EJECTOR TO UTILIZE EXPANSION APART FROM GASEOUS SCAVENGING.

The Duplex scavenging type has been produced under many names both with and without auxiliary blowers, but it is very difficult to obtain satisfactory balance unless horizontally opposed. It is often used four-ported with automatic inlet control to the crankcase and with ejector, so called, scavenging. This is liable to reduce the whirling below the point necessary for rapid explosion.

The object of this design is to obtain reasonably good scavenging; the pistons rising alternately high into the combustion space, assist this, with the aid of the ejector exhaust pipe.

of greater importance directly than either petrol consumption or maximum speed.

Unfortunately, with ordinary methods of control, apart from those of varying compression, etc., the result of closing the throttle is simply, amongst other things, to reduce the effective weight of charge taken into the cylinder, just as if the engine was suddenly transported to an extremely high altitude.

This is bound to introduce the idea of forced feed for all engines, and the two-stroke is in one way a step in this direction, giving as it does a pressure-fed mixture, although unfortunately this mixture is usually obtained from an apparatus which does almost everything but what it should, namely, supply a mixture of petrol *gas* and air. Proper vaporization, proper weight of mixture, lack of inlet shock, and allowance for gaseous and mechanical inertia are really the points which should influence design.

Details of engine speed and reciprocating weights are really offshoots. In nearly every engine there is quite a high vacuum on the inlet side of the system and this naturally has a reducing effect upon the total horse-power,

necessary as it is for the maintenance of mixture even though it may reduce the total volume of gas before explosion.

This is of even greater importance than freedom of exhaust or the maintenance of a fly-wheel effect in the exhaust pipe. In most two-stroke engines, so long as care is taken that the discharge from any one cylinder is not allowed to mix with the discharge of any other until each exhaust port is isolated, no great amount of precaution is necessary. Exhaust freedom is always good.

It is very often noticed that an engine will two-stroke at slightly lower speeds when there is a very slight resistance placed on the exhaust, such as that of a long pipe as distinguished from a pipe of such length as to help ejection. This is due to the suddenness of gas flow and the damping out of eddies and whirling, which occur not only in the ports and pipes, but also over the deflector, however well it may be designed. However well the deflector may be arranged to separate the gases, when the hot exhaust is met by the incoming rush of relatively cold and easily

condensable gas and petrol particles and air, there is bound to be a loss of volumetric and pump efficiency.

WATER INJECTION

A number of very interesting experiments have been carried out to show the effect of mixture-whirling and local cooling. The effect of water injection, for example, on an engine is frequently marked at low speeds, although it should be noted that except in examples of bad carburation water injection should nearly always take the form of liquid water injected on to the hot *metal* parts; so that the heat absorbed may be heat that cannot be directly used in place of a steam reduction of maximum explosion pressure in the hopes of maintaining some pressure at the end of the stroke, which with two-stroke engines is usually impracticable, owing to the early exhaust necessitated by high temperature and the prevalence of crankcase compression.

This is not intended to condemn in any way the practice of using the crankcase as a pump,

because it is doubtful whether any but the simpler forms of pressure augmenters are valuable.

If one has to make use of extra pumping cylinders not only does mechanical friction increase with extra complication even though petrol efficiency may be gained, but the final result is not unfrequently an engine with the same number of actual cylinders as a corresponding four-stroke.

These cylinders might then almost as well be used, were it not for valve gear, to carry an explodable mixture. Two-stroke engines with simple valve gear may yet become popular, as may those built on the double-acting type; this has been applied with great success to many large semi-Diesels, and atmospheric inlet scavenging gas and oil engines fitted with four or more ports.

Experiments have been published from time to time showing methods of studying the exploding mixture and whirlings in cylinders, not only by means of the Low cinematographic method, but also by means of the platinum thermometer to explore the combustion chamber combined with a quartz

glass window in the combustion chamber itself, and the temporary admixture of partially evaporated or visible gases in order that the motion may be observed whilst the engine is running or being driven at equivalent speeds.

It is quite simple by running a two-stroke engine with the crankcase at different temperatures to vary the mean effective pressure over large limits without the addition of any highly volatile ingredients to the fuel.

It has often been claimed that the advantage of a small portion of water to the fuel during its passage through the inlet ports, even if not treated in any way with acetylene or other gas, is able to prevent knocking and reduce carbon deposit.

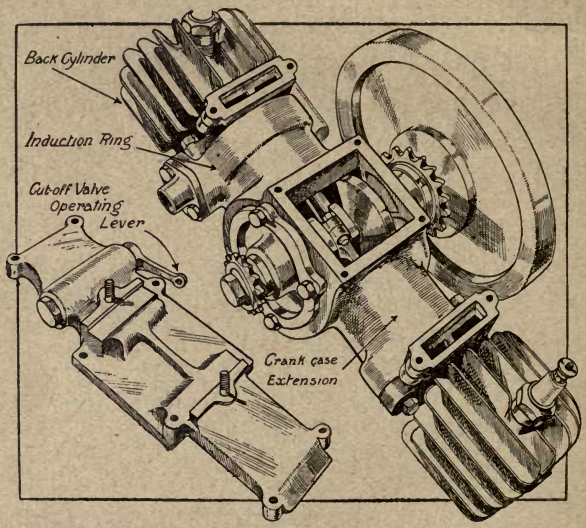
A much more practical method is to make an engine easily cleanable, because knocking has been shown to be due to a large number of causes, and is very often brought about by the taking up of slack and the actual metallic contact of parts usually separated by an oil film in addition to ringing of the metals surrounding and subjected to the explosion pressure.

No internal combustion engines are really flexible, and it is quite extraordinary to find that so little attention has been given to control, whereas all two-strokes really when so called of the valveless type are making use of the sleeve principle for valve porting. They possess many of their good points apart from their mixture losses and cooling difficulties which have become evident on so many of the larger single engines.

It is extremely likely that multi-cylinder engines, especially when constructed on the unit principle containing gear boxes, etc., in one with the crankcase, will become more popular, and we will see still more of these small engines with all their advantages of simplicity, direct piston thrust, and cheapness taking the place of their more complicated, if at present more efficient, rivals.

Some notes are given further on of the simpler methods of calculating pressures and balance weights together with scale drawings of three types of engine (on pages 93, 108, and 182). An idea of the difficulties with which the designer is met will be obtained from their perusal.

It is surprising to find that very little has been done in the direction of pressure-raising in the crankcase by means of exhaust pressure



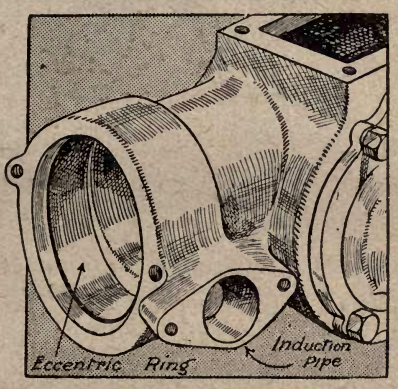
CONNAUGHT HORIZONTALLY OPPOSED TWIN ENGINE.
Showing two-throw crankshaft and magneto platform transfer plate removed (induction ring shown opposite).

or by means of fans, although the N.E.C. engine proved very successful on the latter principle.

The Connaught is another engine which shows signs of very great care in design, and in this case being of the four-port type it has an additional port cut in the wall of the piston

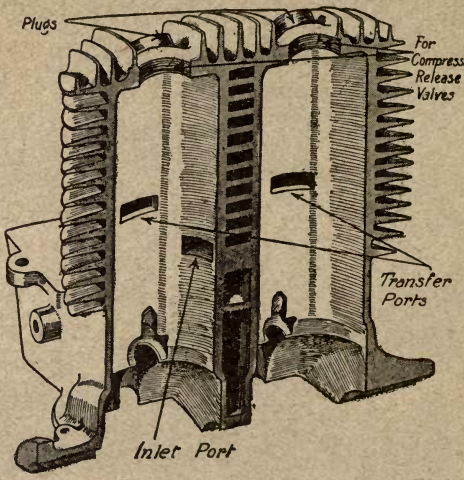
which does not alter the cycle of operations, except for the fact that the transfer port is not put into direct opening to the crank-chamber until its lower portion is uncovered by the piston port. This certainly is an effective method of construction, making a gas-tight joint quite a simple matter and helping to keep the inlet gases warm by their passage close to the exhaust port, both inlet and exhaust being on the same side of the cylinder.

This is a great help towards the perfection of petrol impurities deposition and avoids the use of paraffin for piston-freeing purposes, a by no means uncommon business with many small engines. The Connaught twin is also well worthy of mention, because although it is of the ordinary crank-case compression type the design is rather out of the ordinary, as will be seen from the illustrations.



View of induction ring, into which the inlet ports of the back cylinder lead.

At each end a circular extension is formed on the crankcase which acts as a sleeve to which the cylinder base is bolted. The front sleeve is a fit all round, but the back sleeve is a recessed eccentric induction ring surrounding the cylinder inlet ports and connected up

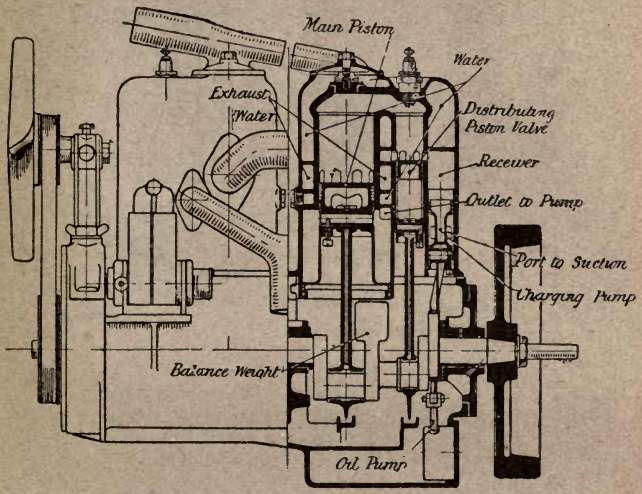


A sectional view of the Allon vertical twin two-stroke. Only one inlet port can be seen, but an identical port is situated on the other cylinder, both opening into a common passage to the carburetter. The Cycaren Engine is similar, but has three cylinders instead of two.

to the carburetter by the ordinary induction pipe; this ring has the converging portion of the eccentric at the opposite side to that of the induction pipe, so that the area of the space

between sleeve and cylinder is gradually reduced, thus making the entry speed of inlet gas as regular as possible.

Four inlet ports are used because the back cylinder is the only one to take in a fresh charge, the front cylinder having the gas supplied to it by way of the transfer port, although of course it draws its share of mixture into the crankcase on the out-stroke



The Record is of the valved pump-piston type, and is somewhat complicated. Piston 2 pumps the charge into the receiver R, from whence the charge is admitted to working cylinder 1 by valve 3. Another piston valve 4 connects piston 2 into communication with carburetter and receiver R alternately. The Record Engine does away with crankcase loss by the use of pump-piston enlargement. There can be no missing of charges and residual gases, and the valve operation is partially assisted by the explosion.

and the remainder of the operations are quite ordinary.

A combined crankcase cover and transfer manifold is employed on this engine, which gives a decidedly neat finish. Both cylinders fire simultaneously, and an arrangement is fitted by means of which one cylinder can be put out of action by closing the back transfer passage.

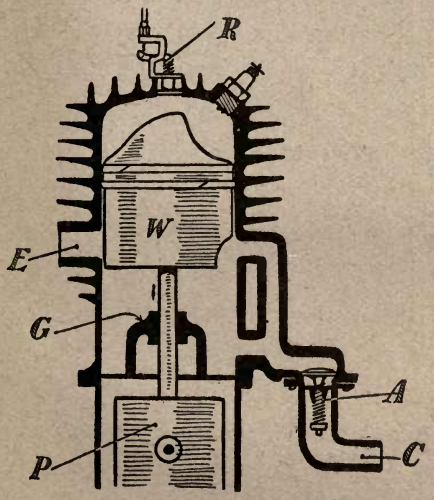
A few notes on the Ricardo engine are interesting as showing the care which has been taken on some pumping cylinder designs to obtain efficiency.

The Ricardo engine is quite simple, as will be seen from the illustration on page 39; no crankcase compression is used, but a separate pump cylinder controlled by flap valves allows the mixture to be drawn in and then transferred to the working side. The cylinders are set at an angle of 65 degrees, and the big end of the connecting rod of the pump is attached to the connecting rod of the working cylinder at the point above its own big end, thus causing the pump cylinder piston to travel faster than the working piston, giving a slightly higher efficiency of charging,

although care is necessary in carburetter setting to avoid condensation due to local shock.

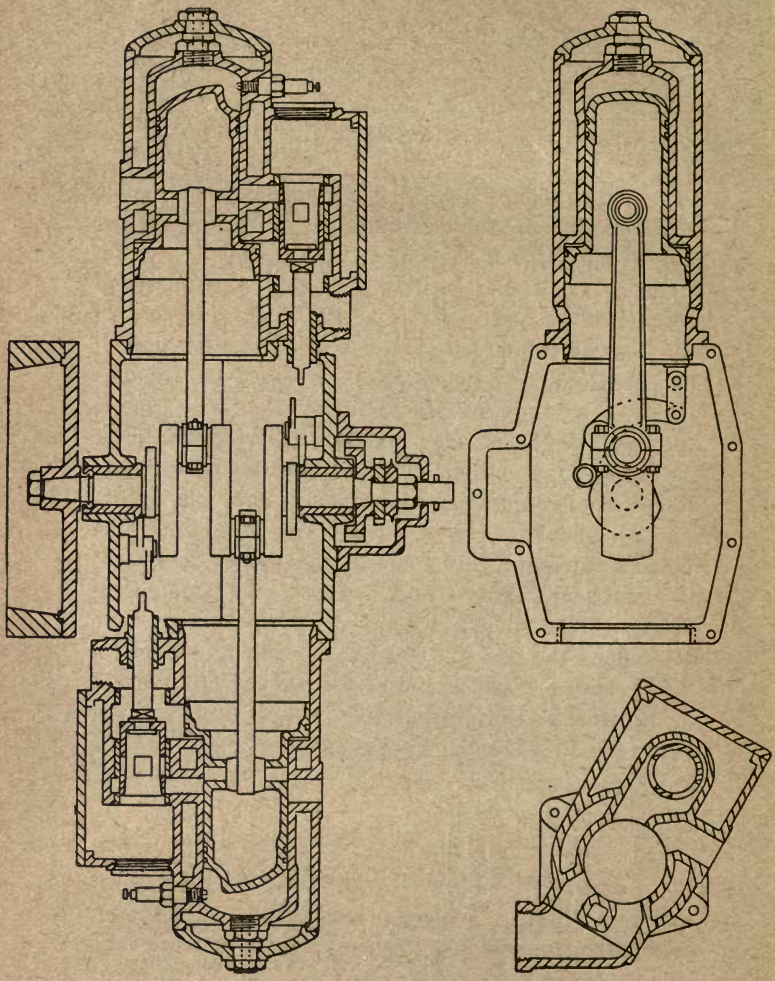
The transfer pipe acts as a compression space for the pump cylinder, but the pressure is seldom more than 5 lb. per sq. inch.

These small Ricardo engines have been very successful and have given up to 12 h.p. at 2000 R.P.M. with a capacity of under 800 c.c. As before, in a description of a special type of engine the illustration has been given (see p. 39) with a few leading notes on the subject. It is very little use to describe each engine in detail, as this can be safely left to the manufacturers.



TYPES OF TWO-STROKE ENGINES.

J. E. S. tandem pump-piston engine. The mixture is sucked from the carburetter by the pump piston, and transferred to the working cylinder. P pump piston, W working piston, A automatic valve between carburetter and pump, E exhaust port, C carburetter connection, G guide for piston rod connecting pumping and working pistons, R compression release valve.



M.I.P. pump piston, piston valve scavenging, horizontally opposed two-stroke.

NOTES ON DESIGNING CALCULATIONS

In a simple book of this kind it would not be possible to go to any appreciable extent into questions of design. It has indeed been the object all through to explain things to the reader entirely from first principles and to show how design, as far as the important part of initial inception and not of mere arithmetic is concerned, is carried out. All engines are, or should be, thought out from a study of principles involved and from a knowledge of the working cycles as can be obtained by the use of the various physical instruments already described in conjunction with experimental engines.

It will, however, be of interest to show, unlike the maker's catalogue, how some of the important details of engines are arrived at when once the volumes of gases and the smooth speeds of exit and entry have determined the port and passage areas and volumes for the avoidance of shock and of too sudden variations of temperature and of pressure.

To take, for example, the *Two-Stroke Forced Induction Engine*, illustrated by working drawings on page 93.

Its capacity is 362 c.c.

Bore	75 mm.	*Check :*
Stroke	82 mm.	$(44{\cdot}17 \times 8{\cdot}2 = 362$ c.c.)

As it is a pressure-fed engine and has its petrol vapour fired after compression, its compression pressure may be high.

Take Compression Pressure $= 120 \frac{\text{lbs.}}{\square''}$.

Then if v = clearance volume by the ordinary rule we have:

$$\frac{135}{15} = \left(\frac{v+274}{v}\right)^{1.3}$$

Whence clearance vol. $v = 62$ c.c.

Exhaust ports, etc., on this engine are a good example of average practice.

Exh. port = 22 mm. deep.

Charge volume is reckoned from 2 mm. below top of ports.

$$\text{Charge vol.} = (8{\cdot}2 - 2{\cdot}0) \times 44{\cdot}17$$
$$= 274 \text{ c.c.}$$

C, the Compression Pressure at Starting, should not be greater than 75 $\frac{\text{lbs.}}{\square''}$.

$$\text{If } C > 75 \frac{\text{lbs.}}{\square''},$$

$$\text{then } \left(\frac{v}{62}\right)^{1.3} = \frac{90}{15} \text{ and } v = 246.$$

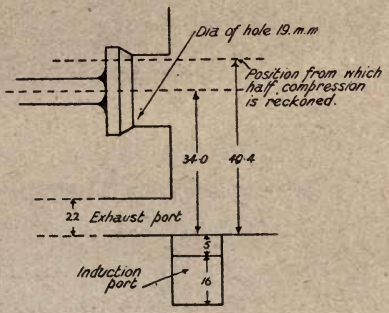
Whence v is the total volume down to the compression release.

$$\text{But total vol.} = 362 + 62$$
$$= 424.$$

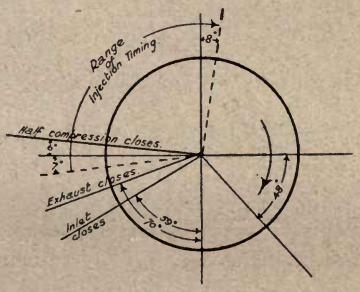
Or $424 - 246 = 178$ = vol. above bottom of exhaust ports to compression release.

$$\text{So that distance} = \frac{178}{44{\cdot}17}$$
$$= 40{\cdot}4 \text{ mm.}$$

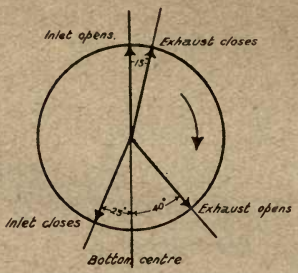
A diagram is given on the next page explaining to where the figures refer.



The arrangement of ports on this engine is a good all-round two-stroke setting. A four-stroke diagram is shown also for comparison.



FORCED INDUCTION AND THREE-CYLINDER TWO-STROKE, PORT-SETTING DIAGRAM.



FOUR-CYLINDER FOUR-STROKE TIMING FOR COMPARISON

Let us now take the example of the

M.I.P. 1100 c.c. twin horizontally opposed engine.

To decrease length, some engines have now strokes shorter than bores and are using enclosed fly-wheels, which, however, decreases pump compression; we will take equal bore and stroke.

Or for example :—

Bore $=88$

Stroke $=90$

$$\text{Capacity} = 60{\cdot}82 \times 9 \times 2$$
$$= 547{\cdot}4 \times 2$$
$$= 1095 \text{ c.c.}$$

Now the volumetric efficiency of charging cylinder has been found to be ·89.

$$\text{Hence diameter of charging piston} = \sqrt{\frac{1+1{\cdot}1}{{\cdot}89}} \times 88$$
$$= 132 \text{ mm.}$$

$$\text{Compression Pressure in Working Cylinder} = 75 \frac{\text{lbs.}}{\square''}.$$

As before *clearance volume* v is obtained thus :—

$$\frac{90}{15} = \left(\frac{v+547}{v}\right)^{1.3}$$

Whence $v = 184$ c.c.

Offset of cylinders not to obtain dwell but in consequence of plain crankshaft

$= 48$ mm.

Estimated revolving weight $= 1{\cdot}55$ lbs. per cylr.

Centrifugal couple $= (\omega^2 r)\ 1{\cdot}55 \times 4{\cdot}8$

$= 7{\cdot}4$ cm. lbs.

Distance between weights $= 9{\cdot}5$.

So weight at crankpin radius $= \frac{7{\cdot}4}{9{\cdot}5} = {\cdot}78$ lb.

With malleable iron weights.

This will show the methods of working out the simpler balancing forces.

Let us take the example of *a Pump Cylinder horizontally opposed two-stroke of* 500 c.c.

A bore of $59 \times$ *stroke of* 10 is inconvenient for two-stroke port design and high speeds.

So we will take : Bore 63

Stroke 80

Volume of each cylinder $= 31{\cdot}17 \times 8 = 249{\cdot}4$.

Charging Piston.

At full throttle amount delivered by charging piston is to be $1{\cdot}1 \times$ volume swept out by piston. This allows for slips, friction leakages and volumetric pumping " efficiency " of the engine.

Diameter of charging piston $= \sqrt{2{\cdot}1} \times 63$

$= 91$ mm.

Compression pressure in receiver is to be 10 $\frac{\text{lbs.}}{\square''}$.

So volume swept out $= 1{\cdot}1 \times 250$.

If $v' =$ clearance volume,

Then $\frac{24{\cdot}7}{14{\cdot}7} = \left(\frac{v' + 275}{v'}\right)^{1{\cdot}3}$

Whence $v' = 572$ c.c.

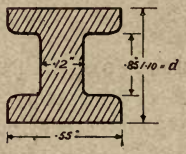
Also the Compression Pressure in working cylinder is to be 75 $\frac{\text{lbs.}}{\square''}$

$$\text{Or } \frac{P}{p} = \frac{90}{15} = \left(\frac{v'' + 250}{v''}\right)^{1.3}$$

Whence clearance volume v''

$$= 84 \text{ c.c.}$$

Then for balancing, as in the sketch, *connecting rod.*



Radius $r = 40$ mm. $= 1{\cdot}575''$.. $\quad l = 190 = 7{\cdot}48''$..

Max. R.P.M. $= 3000$.

$$\text{Thus } f = \frac{\cdot 39 w \omega^2 r l^2}{g\left(6 - \frac{P}{EI} l^2\right)} \cdot \frac{d}{2I} + \frac{P}{A}.$$

$$\omega = \frac{2\pi \times 3000}{60} = 330 \frac{\text{rads.}}{\text{sec.}}$$

$$P = 300 \frac{\text{lbs.}}{\square''} \times \frac{\pi}{4} \left(\frac{63}{25{\cdot}4}\right)^2 = 1450 \text{ lbs.}$$

(Neglecting the second term.)

$$I = \frac{BD^3 - bd^3}{12} = \cdot 039 \text{ inch}^4.$$

$$A = 1{\cdot}1 \times {\cdot}55 - {\cdot}85 \times {\cdot}43 = {\cdot}24 \text{ inch}^2.$$

$$W = {\cdot}24 \times {\cdot}283 = {\cdot}068 \text{ lb. per inch.}$$

Consequently

$$f = \cdot 39^{nr.} \times \frac{\cdot 068}{32 \cdot 2} \times (331)^2 \times 1 \cdot 575 \times (7 \cdot 48)^2$$

$$6$$

And in reduction

$$\times \frac{1 \cdot 1}{2 \times \cdot 039} \times \frac{\text{ft.}}{12 \text{ ins.}} \times \frac{\text{lbs.}}{\text{inch.}} \times \frac{\text{sec.}^2}{\text{ft.}} \times \frac{\text{in.}}{\text{sec.}^2} \times \frac{\text{in.}^2}{1} \times \frac{\text{in.}}{\text{in.}^4}.$$

$$w^2 r.$$

$$\text{Therefore } f = 1560 \ldots \frac{\text{lbs.}}{\square''}.$$

Direct stress $\frac{P}{A} = 6050$.

So total stress $= 1560 + 6050 = 7610 \frac{\text{lbs.}}{\square''}$ Safe.

Estimated approximate weight of piston $= 2 \cdot 27$ lbs.

Connecting rod $= 1 \cdot 0$ lb.

Offset of cylinder centre lines $= 4 \cdot 5$ cm.

Recip. weight $=$ piston $+$ half conn. rod $= 2 \cdot 7$ lbs.

Revolving weight $= \cdot 55$ lb.

Unbalanced recip. couple $= 2 \cdot 7 \times 4 \cdot 5 = 12 \cdot 15$ cm. lbs.

(Cannot be balanced).

Centrifugal couple $= \cdot 55 \times 4 \cdot 5 (\omega^2 r) = 2 \cdot 48$ cm. lbs.

Distance between centre of balance weights $= 8 \cdot 2$ cm.

So weights required $= \frac{2 \cdot 48}{8 \cdot 2} = \cdot 30$ lb. at crankpin radius.

(With balance weights as part of crank web.)

We will now take a *three-cylinder monobloc, two-stroke crankcase compression.*

Bore 75. Stroke 82. Capacity 1086·8 c.c. That is 362 c.c. per cylinder.

For great freedom of gaseous flow we have used two exhaust and two inlet ports, as wide as possible and with pinned rings on piston.

Exhaust ports = 25 mm. wide, 22 mm. deep, area 11·0 . . □ cms.

Transfer passage = 34 wide × 21, area 7·1 . . □ cms.

Transfer ports = 2 (24 wide × 16 deep), area 7·7 . . □ cms.

Carburetter ports = 2 (24 wide × 16 deep), area 7·7 . . □ cms.

Automatic carburetter inlet dia. = 26 mm. (Solex, or better still, wick.)

Effective stroke volume measured above exhaust ports, say 2 mm. below top edges of ports.

$$\text{Effective stroke volume} = (8{\cdot}2 - 2{\cdot}0)\frac{\pi}{4} \times 7{\cdot}5^2 = 274 \text{ c.c.}$$

Compression 73 $\frac{\text{lbs.}}{\square''}$.

Then clearance volume v is obtained as usual.

$$\left(\frac{v+274}{v}\right)^{1.3} = \frac{87{\cdot}5}{15} = 5{\cdot}83$$

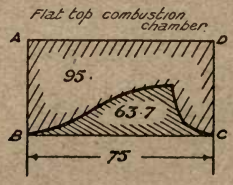
Hence v = 95 c.c.

Volume of piston top (by Simpson's rule) = 63·7 cms.

Total volume ABCD = 63·7 + 95

= 159 c.c.

$$AB = \frac{159}{44{\cdot}18} = 36 \text{ mm.}$$



Then : *Balancing.* (One direction of thrust, as in all two-strokes of this type.)

Revolving weight to be balanced, includes connecting rod up to but not including small end.

Crankpin $=\cdot 23$ lb.
Big end bush $=\cdot 27$ lb.
Big end $=\cdot 27$ lb.
Connecting rod web $=\cdot 28$ lb.

$1\cdot 05$ lbs. concentrated at crankpin.

Volume in steel $=1\cdot 05\times 3\cdot 53\times 16\cdot 4=64$ cm.^{3}

Moment about crankpin

$$=64\times 4\cdot 1=262 \text{ cm.}^4$$

Or *balance weight* at each crank web

$$=131 \text{ cm.}^4$$

And with semicircular weights

$$\bar{y}=\frac{4r}{3\pi}=\frac{4\times 5\cdot 8}{3\pi}=2\cdot 46 \text{ cm.}$$

$$\text{Area}=\tfrac{1}{2}\frac{\pi}{4}\,11\cdot 6^2=52\cdot 8.$$

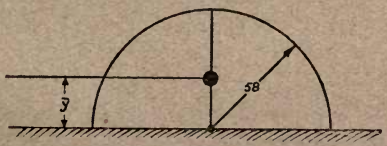
Or moment about crankpin per cm. of width

$$=52\cdot 8\times 2\cdot 46=130 \text{ cm.}^4$$

Hence thickness as per the diagram

$$=\frac{131}{130}=1 \text{ cm.}$$

Or 10 mm. approximate.



Naturally in a three-cylinder engine the only effect of balance weights is to reduce the B.M. on the crankshaft, leaving octave unbalanced forces practically unaltered.

A convenient method of calculating compression is as follows, whilst the effect of removing blowing webs is also shown from a small monobloc light car two-stroke engine.

$$(Sv+Cv) \text{ atmos. press.} = Cp \times Cv.$$

When Sv = stroke volume.

Cv = compress volume.

Cp = compress pressure.

$$\text{Then } \left(\frac{\text{bore}^2\pi \times \text{stroke}}{4}+Cv\right)15 = Cp \times Cv.$$

$$\text{And } C_p = \frac{\left(\frac{B^2\pi \times S}{4}+Cv\right)15}{Cv}$$

$$Cp = \frac{15B^2 \times \frac{\pi}{4} \times S}{Cv} \cdot C.$$

FURTHER CALCULATIONS

The question of crankcase compression is one of importance, because if this compression is too low the volumetric efficiency drops rapidly, and, on the other hand, too high a compression in the crankcase leads to over rapid delivery of the fresh charge with resultant missing, shock and condensation. A compromise is best effected after consideration of port volumes and other data. Methods of calculating these compressions are not hard. With existing engines, the crankcase may be conveniently filled with oil and its quantity measured, not forgetting the volume of the inside of the piston and the transfer port.

Compression pressure is therefore calculated from the *free and compressed* volume in the crankcase by applying the usual formula.

$$P_1V_1^{1.3}=P_2V_2^{1.3}.$$

In the particular unit engine already illustrated the alternative combinations of factors influencing crankcase compression are as follows :—

(A) Oil sump full, and wood cheeks fitted, 8·5 $\frac{\text{lbs.}}{\square''}$.

(B) Oil sump full, no cheeks fitted, 7·5 $\frac{\text{lbs.}}{\square''}$.

(C) No oil in sump, and wood cheeks fitted, 7·5 $\frac{\text{lbs.}}{\square''}$.

(D) No oil in sump, no cheeks fitted, 6·3 $\frac{\text{lbs.}}{\square''}$.

In the case of suction pressure, this may be obtained by similar means with pumping engines, and in semi-atmospheric engines it is merely a question of allowing for frictional and time entry losses. A low charging pressure is usually best to avoid the result of high pressure ; that is to say too rapid a suction on the carburetter. Many engines can be improved by the use of a fairly large volume of gas (kept warm) between the choke of the carburetter and the inlet or transfer ports.

When one or other of the clearance volumes or compression pressures are known the other may be calculated from the same formula :

$$P_1V_1^{1.3}=P_2V_2^{1.3},$$

where P_1 and V_1 refer, say, to the atmospheric pressure and volume of the charge in the cylinder and P_2 and V_2 to the corresponding compression pressure and volume.

Suppose, for example, the clearance volume is required for an engine as follows :—

Two-Stroke Engine : Bore and stroke 75×82 mm.

Compression 75 $\frac{\text{lbs.}}{\square''}$ gauge.

(It is difficult to greatly exceed 80 $\frac{\text{lbs.}}{\square''}$ compression on ordinary engines even if the obvious advantages of water cooling are included. In the same manner an extra long stroke even when offset leads to difficulties in dwell and timing.) A correction must naturally be applied, because the atmospheric volume of the charge must be calculated from just below the top of the exhaust ports where the charge is trapped.

Depth of exhaust ports = 22 mm.

$$\text{Effective stroke volume} = (8{\cdot}2 - 2{\cdot}0)\frac{\pi}{4} \times 2{\cdot}5^2$$

$$= 274 \text{ c.c.}$$

Now let v = volume of clearance (compression volume).

Then $\left(\frac{V_2}{V_1}\right)^{1.3} = \frac{P_2}{P_1}$ where P is reckoned as *absolute* pressure.

$$\text{Or } \left(\frac{v+274}{v}\right)^{1.3} = \frac{75+15}{15} = 6.$$

Hence by logarithms:

$$\left(\frac{v+274}{v}\right) = 3{\cdot}972.$$

$$\text{And } v = 92 \text{ cc.}$$

These examples of designing calculations are intended to act as a guide for the checking of other original calculations based on the details laid down previously.

The two-stroke engine cannot be treated as an individual problem. It is one of the largest of subjects, and even if it should become but a stepping-stone to the constant impulse prime mover it should be treated with the thought and respect due to the engine of the future.

The two-stroke engine is—or should be—one of the simplest means of converting chemical energy into mechanical work, and it requires very little knowledge, except that of first principles, to obtain success from its use. One point should always be kept to the fore. An engine should not be asked to do negative work. It should be a power producer. Multiplication of parts reduces it to the level of its corresponding four-stroke, and is a step further from a continuous impulse machine.

The two-stroke engine has yet to be practically introduced to the Realm of Aeronautics, and yet in this one sphere alone its possibilities are enormous. The two-stroke engine will give us even torque without propeller flutter, it will run steadily, particularly at one speed, and be economical at this speed, which is just what the Aeroplane requires. There are fewer parts to get out of order than exist in almost any other form of power plant.

Final Hints for Owners of Two-strokes.

Keep all ports, pipes and silencers clean and smooth-edged. Remove carbon from the piston rings and sharp edges from deflector plates.

Long-reach plugs are not always best. Use a wide gap and keep the magneto oiled.

Work all joints carefully, and clean the passages and gauzes. Use a rather low level in the jet and warm the carburetter.

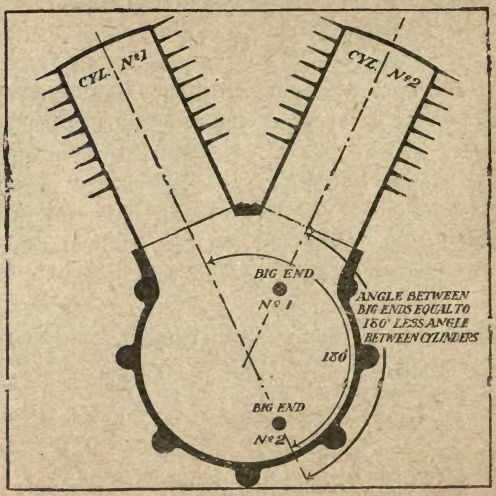
Spark timing should be well advanced.

With petroil engines shake the machine before the first start in the morning.

Remember what the engine is called upon to do in each of its details and accessories; there is no more willing engine than the two-stroke.

The following notation is very useful for kinematic formulæ; thus a two-cylinder two-crank engine horizontally opposed 339 C is expressed:—

2·2·180 C 339 c. C meaning crankcase compression. The same nomenclature is applicable throughout.



TYPES OF TWO-STROKE ENGINES.

The Peco two-stroke twin possesses satisfactory balance and torque and a compact construction is obtained. Two outside fly-wheels are fitted and the inner bearing, quite properly, does without any inner packing gland. The diagram shows manner in which the big ends are set at 180 degrees.

THE END

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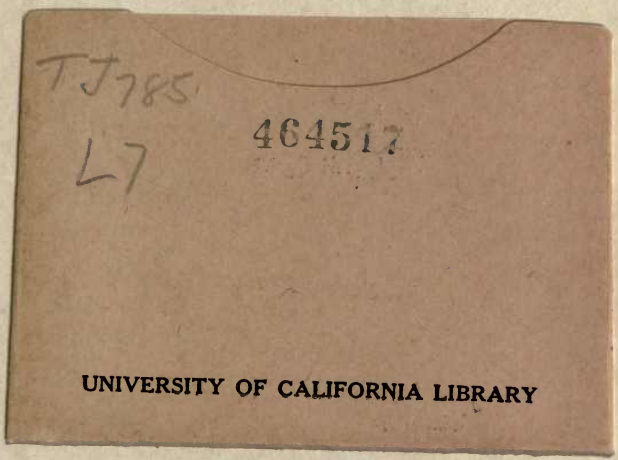

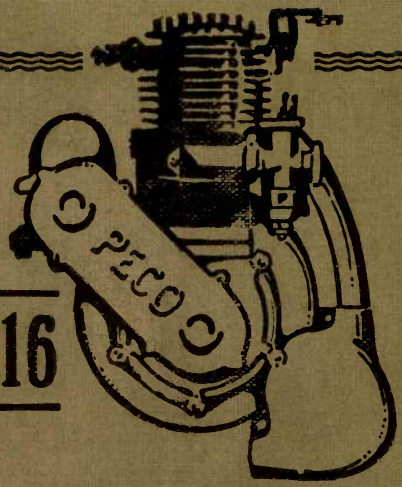

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